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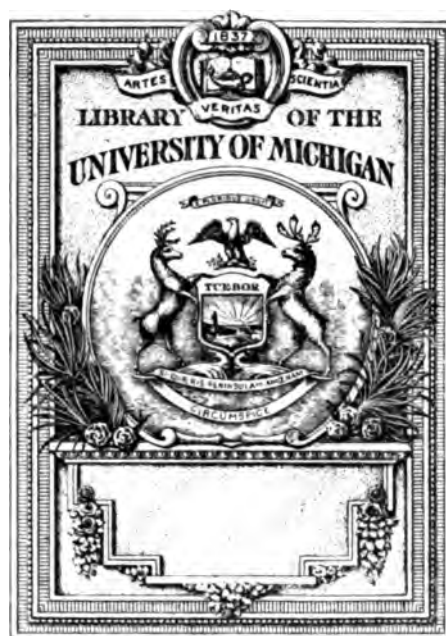
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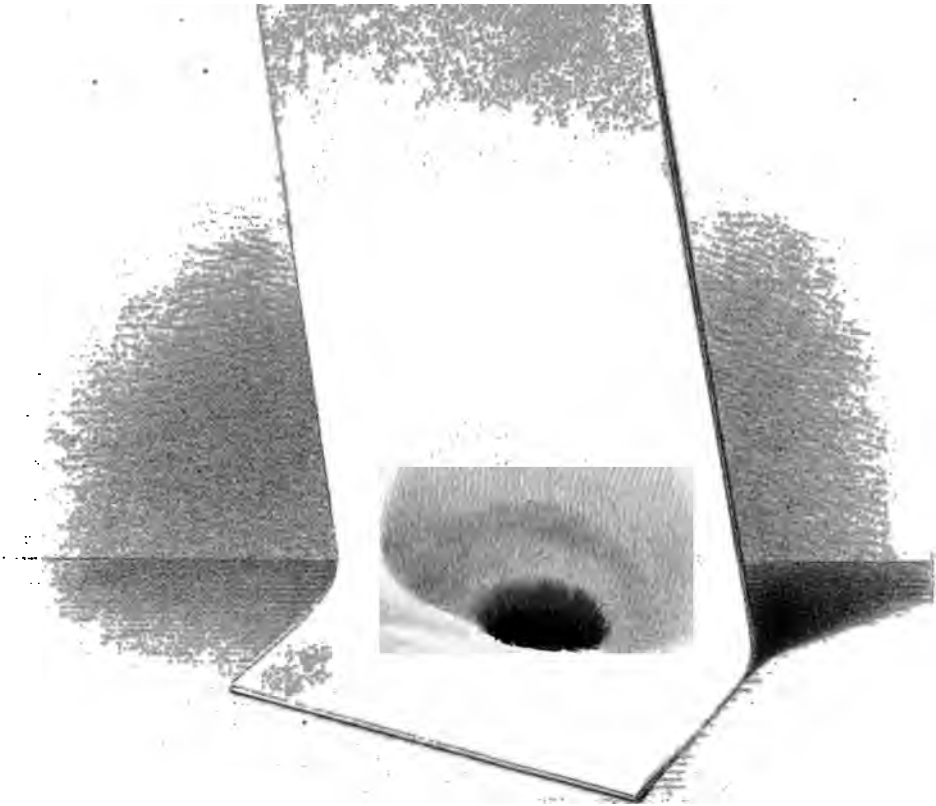
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SUBLIMATE OF GOLD ON ALUMINUM PLATE.

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PYROLOGY, OR FIRE CHEMISTRY;

A SCIENCE INTERESTING TO THE GENERAL PHILOSOPHER,

AND

AN ART OF INFINITE IMPORTANCE

TO THE

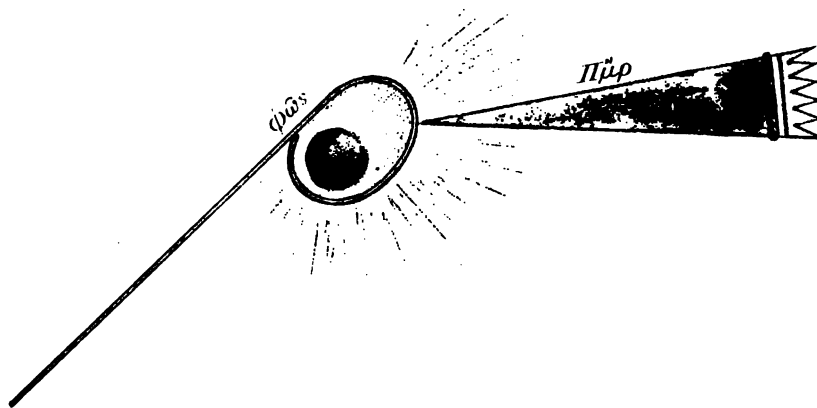
CHEMIST, MINERALOGIST, METALLURGIST, GEOLOGIST, AGRICULTURIST,
ENGINEER (MINING, CIVIL, AND MILITARY), &c., &c.

BY

WILLIAM ALEXANDER ROSS,

LATELY A MAJOR IN THE ROYAL ARTILLERY.

"De secretis Naturæ et Artis Operibus."—FRATER ROGERIUS BACO.



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1875.

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To the Memory of
THE IMMORTAL SWEDISH
BERZELIUS,
OF THE NEVER-TO-BE-FORGOTTEN GERMAN
PLATTNER,
AND OF
ROBERT BOYLE,
FATHER OF PYROLOGICAL CHEMISTRY,
I DEDICATE
THIS BOOK.



P R E F A C E .

WE find ourselves, when our minds are fully developed and healthy, living upon this "inconspicuous globule,"* earth, apparently for the purpose of determining, or rather of trying to determine, a seemingly infinite series of questions placed before us for solution. That these questions imperiously and incessantly press themselves upon the consideration of every man or woman who is able to think at all beyond the thoughts, which possess most too sorely, of the ordinary anxieties of life, and of "provision for the morrow," surely constitutes sufficient evidence of such a *design* of our existence?

In asking ourselves these inevitable questions, we may either commence from the top, and reason downwards, or from the bottom, and reason upwards, regarding the natures of things. We may begin by saying, "What are we? What constitutes the mind? What these mental aspirations after the possession of an eternal spirit or soul, in addition to that of our finite reasoning faculty, and the secret dissatisfaction the knowledge of our animal-like mortality creates? Have other animals minds in a lesser degree? Is their flesh and blood precisely like ours? Are the bodies of *all*, and *all* vegetable material, built up and sustained by the *mineral* constituents we find existing in every organic substance, solid or fluid,† in howsoever small a particle? If so (and it is so), have our bodies, and those of trees, &c., originally sprung from those constituents? If so, in what particulars does their present existence differ from ours? &c.

Or we may commence with, "What are rocks and stones? How did such a vast ball of them as this earth become conglomerated? To what is terrestrial heat really due? From whence were originally derived the enormous quantities of nitrogen and oxygen in the air? Is any part of those gases lost in space? If, as we find the case, seeds and plants, which have invariably mineral constituents, are also invariably nourished and sustained in matter composed of the attrition of these rocks and stones which we call "earth," could the first seed have been evolved out of earth? As calcic phosphate and silica are the chief mineral constituents of all organic bodies, could vegetable or even animal *life*, by any peculiar operation of time and circumstance, aided by certain conditions of heat and moisture, be developed out of those? Both the ascending and descending series of questions, however, must stop at this one: What is vitality?

* 'Essays and Reviews,' p. 249.

† Cane sugar seems an exception to this fact; gum and starch are *not*.

Even vegetable life is a fact or secret of such ineffable subtlety, that it utterly defies the most delicate human analysis.

In the attempt to answer satisfactorily such questions, we at once light upon the assumable origin of the "arts and sciences." For instance, as regards sciences, the subject of "What are we?" constitutes the science Biology. "What is the human mind?" Psychology. "What are rocks and stones?" Geology and Mineralogy. "Whence were the nitrogen and oxygen in the air derived?" Chemistry. It is equally evident that from the practical investigation of these subjects most of the arts have been educed. As examples, an inquiring treatment of a silicious stone, like commercial *Cassiterite*, in a fire made from wood and vigorously blown upon, would probably result in the production both of small globules of tin, and of a considerable quantity of glass. A philosophical examination of gold, to see if it is really such a "fixed" metal as it is stated to be, results in the production of the beautiful pigment called "purple of Cassius" (which was first described, however, by Neri in 1601, thirty years before the elder Cassius wrote), &c.

It further appears that the practice of the arts, when pursued with sufficient intelligence, has often supplied us with new trains of ideas, from which distinct branches of science have also sprung.* Pattinson crystallizing lead out of silver-lead, with *hot* ladles, and thus opening up a problem in calorimetry. Chevreul suspecting the nature of fatty acids and glycerine, by simply subjecting olive oil to a low temperature for a considerable time, are instances. Science and art are thus seen to act and re-act upon each other with an almost exchangeable importance. Science is theoretical art; art practical science; and the attempt to separate these two, and to inculcate what is called "pure science" (so called, I presume, on account of its barrenness), which seems as common to-day as in the time of Socrates and Plato, can be proved to have the most disastrous effects; for the commonest arts, even when practised by ignorant, unobserving people, often give rise to philosophical questions, which mathematics or metaphysics alone are hopelessly helpless to answer.

It is painful to think that some of the cleverest men and deepest thinkers of this age are misapplying their talents in splitting metaphysical hairs and mathematical straws with the most admirable precision and erudition. If such a writer as Herbert Spencer, for instance, had applied his keen apprehension and unrivalled observation to the subject of *practical* inorganic analysis, what important discoveries might not have been hoped for? Instead of this, here is

* As I write, the 'Times' of 6th February, 1875, has appeared, in which is the account of a discovery by a French *farmer* which makes glass as *tough* as talc, by simply annealing it from red heat in oil. What "laws" may not this important discovery elucidate? Stephen Hales, however, describes a precisely similar process in 'Vegetable Staticks.' London. 1727. Page 185.

a specimen of the thorns which have been garnered for us from his philosophy, by this great thinker: "Matter then, in its ultimate nature, is as absolutely incomprehensible as space and time. Frame what suppositions we may, we find, on tracing out their implications, that they leave us nothing but a choice between opposite absurdities."* And again: † "The conviction is reached that human intelligence is incapable of absolute knowledge; and . . . the reality existing behind all appearances is, and must ever be, unknown." The first of these conclusions is by no means new, and is ascribed by Bacon, with reference to the same, or a similar argument, to "impotentia mentis."‡ In the attempted proof of the second, it is rather surprising to find old Verulam himself—"the great apostle of experimental philosophy"§—cited, according to Sir W. Hamilton, as a witness; he, however, in the very paragraph of the 'Novum Organum' above quoted, says, "Est autem æque imperiti et leviter philosophantis, in maxime universalibus causam requirere, ac in subordinatis et subalternis causam non desiderare," a passage which seems not only to admit the existence of absolute knowledge of the humblest description, but to speak slightingly of those who "look for causes in the highest universals." In another part of the same unrivalled work || he plainly declares that the subordinatis et subalternis refer to "concrete" facts, which require absolute (not relative) knowledge for their appreciation.—"Si qui diffidant, me videant, . . . in hac re plane protopirum, et vestigia nullius sequutum, neque hæc ipsa cum ullo mortalium communicantem; et tamen veram viam constanter ingressum, et *ingenium rebus submittentem* hæc ipsa aliquatenus provexisse." Perhaps, however, the metaphysicians and mathematicians have sarcastically produced Bacon in court as an evidence on behalf of the very reasoning he condemns and deplores throughout the 'Novum Organum,' *en revanche* for the highly disrespectful way in which he compares them, surrounded by the split hairs of their arguments, to "spiders, which spin webs out of their own bowels" (araneorum more, telas ex se conficiant).¶

The fact is, "pure" logical and mathematical abstractions, however precise and exact they may seem, lead us to nothing; or, what is worse than nothing, "unthinkable" results and religious scepticism. It may be fairly said of "pure" mathematicians and metaphysicians—to paraphrase an old saw—

Small doubts breed great doubts, and greater doubts to fright 'em.
These doubts bring greater doubts; and so, *ad infinitum*.**

* 'First Principles,' p. 54.

† *Ibid.* p. 68.

‡ 'Novum Organum,' lib. i. xlviii.

§ Macaulay's 'Essays.'

|| Lib. i. cxiii.

¶ Lib. i. xcv.

** "Each new ontological theory, from time to time propounded in lieu of previous ones shown to be untenable, has been followed by a new criticism, leading to a new scepticism."—Spencer, 'First Principles,' p. 68.

Mr. Herbert Spencer tells us, in the 'Prospectus' of the 'Instauratio Magna,' which he has been for so long working at, that, after the "First Principles, should have come, in logical order, their application to Inorganic Nature. But this great division it is proposed to pass over, partly because even without it the scheme is too extensive, and partly because the interpretation of Organic Nature after the proposed method, is of more immediate importance."

There seems, however, to have been a still more powerful influence than either of those mentioned, causing Mr. Spencer to "pass over" this important division of his subject. He would have had to admit the "special creation" of sixty-three elements—chiefly metals—said to combine with each other chemically, in definite proportions; and such facts could not merely not be adapted to his "evolution" theory, but must, when admitted, utterly upset that. Now, if such a candid and keen inquirer as Mr. H. Spencer is had examined this "great division" by means of the light thrown upon it from pyrological analysis, he would have admitted the weight of evidence to gravitate the conclusion that metals are not elementary substances, for they are all decomposable into the *same* appearances: * he would have found that they are never free from traces of each other; as, for instance, that lead *invariably* contains auriferous silver† and antimony; that they offered, when sufficiently closely analyzed, such appearances as would be consistent with an hypothesis that the most perfect metal had been gradually formed during an indefinite period of time, perhaps from the least perfect; in short, that transmutation of metals is not a whit less probable than transmutation of organic species, though either can only be effected by means of the agent, immense time. No doubt Mr. Spencer could also make "ontological" use of the curious facts, (a) that by merely heating a piece of pure zinc in a bead of boric acid the very nature of the former is so changed that the resulting ball of metal, extracted by boiling water, and re-heated alone on charcoal, no longer affords a sublimate, but oxidizes over its surface like tin. A chemist who analyzed such a metallic ball for me with hydracids, &c., informed me that it contained aluminum and other things, although the zinc treated by both of us was one of his own reagents. (β) That differential molecular motion may be initiated in the metals composing a nearly cold alloy by simply heating one side of it only.‡

Instead of the *practical examination*, where possible, of philosophical questions, it is the fashion to-day to apply for their elucidation only logical hair-splitticisms, or algebraical manipulations. The old dispute between Kant

* See pp. 10, 11, of this work.

† See pp. 249, 252, 288. I purchased, a few days since, a common cut glass tumbler, which is tinged all over with a "rose" tint, from the auriferous silver-lead contained in it. This coloration seems erroneously attributed to manganese.

‡ Page 239.

and Hume about the "law" of psychological association is revived, and Kant's famous position, that it is impossible the fact that the angles of any triangle are equal to two right angles could have been ascertained by "experience," is maintained.* Now it seems at the least probable that the very idea of a triangle or of any other form, *must* have been derived originally from "experience." It was perhaps suggested by some such mineral as *Tetrahedrite*, or by such an animal as a star-fish, by connecting three radial points of which latter with slips of wood, a figure is produced from which the above-mentioned theorem is self-evident, and can be fairly supposed to have possibly suggested itself to the mind of a contemplative savage, before the time of Thales.

Turning from metaphysics to physics, we find that whole subject placed under the entire control, and, indeed, *direction* of mathematics, in spite of Bacon's warning: "Magna ista scientiarum mater (physics) *mira indignitate* ad officia ancillæ detrusa est; quæ medicinæ aut mathematices operibus ministret,"† and his dictum that "mathematique is a branch of metaphysique."‡ Without for a moment contesting that mathematical formulæ may be absolutely necessary to explain the action or utility of complicated machines and apparatus, such as we see figured so beautifully and correctly in 'Ganot's Physics,' it is at least equally certain that no really important terrestrial *discovery* has ever been, or ever will be made by means of mathematics. Even in purely artificial cases, where mathematical reasoning is put *en train* by previous discovery, and in which it might be supposed to be fairly appealed to in order to clear the way for further practical experiment, it seems to have utterly failed in originating or even suggesting anything. Such a case is supplied by, perhaps, the most important invention of modern days, the locomotive engine. For a long time it was supposed that, for want of the necessary *friction*, driving wheels would slip along the smooth rails, and in this mistaken idea much valuable time was lost and great expense incurred in the contrivances of cog-wheels and ratchets, &c. Now here, if ever, was a case where one might have supposed "pure" mathematical reasoning would have held a light to practical experiment; but it failed to do so. The discovery of the planet Neptune, indeed, can be properly adduced as a "purely" mathematical one, though even there, "experience" of the perturbations of Uranus seems to have preceded calculation; but "Mathematique" may fairly call Astronomy her peculiar province.

On what account, then, are mathematics generally esteemed in Europe the most absolutely essential of all sciences, without which the humblest scientific efforts are not to be exerted? Even poor old Mrs. Marcet, who, Lord Macaulay

* See the 'Contemporary Review' for October, 1874.

† 'Nov. Org.,' lib. i. lxxx.

‡ 'Adv. of Learn.,' book ii., p. 150.

says,* "could have taught Montague or Walpole many lessons in finance," apologizes for "her ignorance of mathematics, and the imperfect knowledge of natural philosophy which that disadvantage *necessarily implies*," with an absurdity of affectation which reminds one of the Nigger who could not sing because he had a blister on his great toe. Mathematics are, to-day, allowed twice as many marks in every public examination as are allotted to proficiency in any other science, whether by cadets or clerical neophytes, who, however, not once in a thousand cases keep up the study in after life. Bonaparte is supposed to have utilized his marvellous military genius by mathematical calculations, and he encouraged the absurdity himself, just as he pretended to be a Mahomedan when in Egypt. Newton is supposed to have discovered the prismatic mode of analyzing light, not so much by means of his natural genius, a gimlet, a shutter, a three-cornered piece of glass, and the previous assertion of Grimaldo,† that light was "shattered" by the latter of those, as from abstracted mathematical manipulations. In the same way, the same genius applied his observation of the falling apple (for there is no disproof of that account) to the motions of the planetary system; and his observation of a heap of moist panes of glass with iridescence between them (which so many of us have seen but not observed), to the problem unsolved by the indefatigable but futile mica-splitting of the mathematician Hooke.

At present, the inscription of Plato over the entrance to his academy or grotto, "No one not a geometer need enter here," is absolutely applicable to the teaching of so-called "*natural* philosophy" in England and France, although, except as regards crystals, there is not a straight line in nature, nor a crooked one in geometry; but a school of philosophers is gradually arising in England and Germany who are boldly and successfully asserting the right of applying only plain English, German, or whatever their native language may be, to the solution of all really natural, that is, experimental, problems. Plato thought that the use of letters was "a support which made vigorous exertion first unnecessary, and then impossible, and that the powers of the intellect would have been more fully developed without their delusive aid;"‡ and to what this and other abstracted ideas led him, may be clearly seen by comparing the profound, philosophical, and luminous investigations of the 'Novum Organum,' with the flippant, shallow, and (in Book v.) grossly indecent abstractions of his 'Republic.'

* 'Essay on Milton.'

† Grimaldo's theory was, "that the light, in passing through a prism, acquires colors which it had not before, and, moreover, that every ray is shattered, dilated, and split into many other diverging rays, painted of a different color; and this is the reason why the image is colored, and of an oblong figure." (See Algarotti's 'Newtonian Philosophy,' Eng. trans. 1789. Vol. ii., p. 28.)

‡ Macaulay's 'Essays,' p. 400.

As it is the custom, to-day in England, to "confirm" by mathematical investigations the obvious solutions arrived at by common sense, plain English, and practical experiment,—although, if an invention be practically and profitably important, it surely cannot matter a brass farthing or a British halfpenny whether it can be mathematically proved to "rest on sound principles," or not—we may, *en revanche*, apply a merely linguistic examination to the acquirement of some knowledge as to what "the god-like science" of mathematics really is. First, then, we find the essential part of the science is undeniably algebra, or the use of algebraical signs, symbols, and mode of reasoning. Deprived of these, mathematics would sink or rise to a kind of arithmetical geometry. If this position be denied, it can apparently be proved. Next, we find that, so far as mathematics cannot be denied to be a medium of the translation of thought from one mind to another, to such extent they may be assumed to be essentially a language, although one of symbols, just as a speech may be stenographically expressed. Third, we find that algebraical reasoning consists essentially in the *manipulation* of (artificially) symmetrical clusters of facts and assumptions, in a contracted or symbolical form: in their transposition, inversion, submission to the action of coefficients, &c.; a manipulation which Bacon, speaking of the mathematical abstractions or *idéas* of Plato, long since exposed as "*axiomata ex tenui et manipulari experientia, et paucis particularibus*;"* which expression is amusingly rendered by his mathematical translator "*unassisted experience*." The fact seems, that the algebraical mode of reasoning requires chiefly *dexterity* in manipulation on the part of the operator, and the most absolute *attention* (which is only another name for memory) to technical data and first-obtained results. It may be termed a sleight of mind—a kind of mental conjuring, rather than a medium of employment for the *whole* intellectual capacity. Given certain data, it conducts the manipulator with marvellous rapidity and precision to certain results, but the reasoning must be confined to an authorized and not very broad groove. It is a kind of ratiocinating railway, in which the operator enters, and is shut up, whisked rapidly along, and deposited with unerring precision at a definite point; but he sees nothing of the surrounding country on his passage, and if he deviate but for one moment from the rigid rails of his "*manipulari experientia*," if a single term be mistransposed, or a coefficient misapplied, an utter smash of reasoning is the result, and his work becomes a mere mass of gibberish.

It is difficult to understand how, under such conditions, the study of mathematics can be, as it is universally adduced, the best means of *strengthening* the mind. It would seem rather to weaken the general qualities of that, by unduly fortifying one particular, unfaltering attention to certain dexterous contrivances,

* 'Nov. Org.,' lib. i. xxv.

and thus allowing the thinker to save the causative faculties, by trusting to his remembrance of those. Sir John Herschel seems (unconsciously) to admit this position in the introduction to the discussion of a subject, for the proper understanding of which all admit the absolute necessity of mathematical knowledge—astronomy; for he says, comparing the astronomical acquirements obtainable by “practice and experience” with those by “a sound and sufficient knowledge of mathematics,” “The difference is that of *pioneering a road through an untraversed country, and advancing at ease along a broad and beaten highway.*” *

But it must be evident that to “advance at ease” to the knowledge of a subject by means of a mathematical “highway,” that subject must be absolutely bounded by and based upon rigid “laws” or unelastic quantities, which are insusceptible of change. Now the more, and the more closely we inquire, we find less and less reason to assume anything of the sort with reference to the operations of Nature. We find, on the contrary, a gradual but never-failing *change* occurring, both as regards material and dimension, in everything; and not this only, for we can see no such thing as distinct lines or demarcations between the natures of things, which rather seem to glide insensibly from one to another, until this passes into that, excepting ultimate or primordial traces of some element common to both, which can only be detected by the most minute analysis. Mathematics will never enable us to grapple with the difficulty of investigating the real nature of such changeable quantities, even by attempting the explanation of artificial phenomena which may seem to remain unchanged. For instance, I showed a friend, a Cambridge Wrangler and Fellow of Trinity College, the remarkable difference there is between the shape of the *blast* from a blowpipe, as seen in a spirit-lamp and candle flame respectively, by reflected and transmitted light: it having in the first case a *conical*, and in the second a *linear* appearance.† I asked him to suggest a reason for this curious difference in the shape of the same thing, but he said “he could suggest nothing.” Now, this gentleman is not merely a first-rate mathematician, but possesses naturally a most inquiring and originating mind, though (as I maintain) those qualities have been injured by his too great devotion to abstruse mathematical problems.‡

The question then recurs, Why is a sound and sufficient knowledge of mathematics held in England and France to be the *sine qua non* of the thorough attainment of almost every science, when, by the evidence of numerous facts, we

* ‘*Outlines of Astronomy*,’ p. 6.

† *Vide* pp. 55, 58.

‡ “However consistent other sciences may be with professional avocations, mathematics, from its extreme difficulty, and the overwhelming attention which it demands, can only be pursued with success by those whose leisure is undisturbed by other claims.”—Babbage, ‘*Decline of Science in England*,’ page 8.

find it in reality to be not merely of little use, but positively injurious to that of most? One answer seems, that so many of our most eminent men and profoundest thinkers emanate from Cambridge and Oxford (the last English stronghold of "pure" mathematics), that we fall into the common error of accepting effect as cause. These men are eminent in ordinary pursuits, in spite of, not on account of their mathematical education. Our most promising and remarkable youths are almost invariably sent to those Universities, and we attribute to "Alma Mater" alone what is almost entirely due to Mater Natura.

If, indeed, the laws of nature were as formulable, formidable, and numerous, as they are stated to be (for instance) in Ganot, where twenty-three such laws may be counted from p. 11 to p. 38, without going further, mathematics could rightly claim to guide all investigation in natural philosophy; but we find that the greater part of these so-called "laws" are derived from the operation of complicated artificial machines and apparatus; a philosophy as really "natural" as would be the investigation of nebulous phenomena by means of the steam emissions from a locomotive. "Necessitas non habet leges," says the Eton Latin Grammar, and it would appear that invention (which is merely another name for nature discovered) is the daughter of necessity, and still less likely to be bound by human laws. We have reason to suspect, in short, that the real laws of nature are *extremely* few, and simple; the great discoveries of Newton forming a large part of them.

In Newton's "Rules of Philosophizing" * we are distinctly cautioned against multiplying "laws" of nature—a warning still more solemnly given in many parts of the 'Novum Organum'; but the French, who are the great artificial-natural law-makers for Europe, seem to think that there is no limit, either as to number or direction, in the mathematical manufacture of "laws." Chevreul, himself too good an experimenter to be a law-maker, gives us an amusing illustration of this curious tendency on the part of his countrymen. He says,† "My friend, Ampère, whenever, in the course of my researches, I mentioned to him anything relative to contrast (of colors), constantly replied, *"So long as the result of your observations is not expressed by a law, they are valueless to me."* M. Chevreul then naïvely states that "he had great difficulty in finding a law"; but one evening, sitting beside Ampère at a prosy lecture, he suddenly thought of the "law of simultaneous contrast of colors," which is about the only foolish thing in his admirable work cited below.

The discovery by Higgins‡ and Dalton (1803) of definite combining

* 'Principia,' book iii.

† 'Principles of Harmony, and Contrast of Colors,' p. 417, Eng. trans.

‡ 'A Comparative View of the Phlogistic and Antiphlogistic Theories.' 1789.

proportions in hydracid chemistry,* on which the atomic theory of the latter was based, opened a door for the application of mathematics to chemistry, of which the votaries of either science were not slow to avail themselves. "It can happen to but few philosophers, and but at distant intervals, to snatch a science like Dalton (*sic*) from the chaos of indefinite combination, and binding it in the chains of number, to exalt it to rank among the exact." † No doubt, so far as the expression "number" extends, this eulogium is correct, but it may be doubted if the algebraico-chemical equations, *minus* the minus sign—which have been generated by this beautiful theory—have really furthered the progress of practical chemistry.

"Chemistry is a French science," triumphantly exclaims M. Wurtz, in the preface to his 'Chemical Dictionary'; and although the assumption is indignantly denied by his English translator and other distinguished chemists, there seems little reason to doubt that the brilliant discoveries and ingenious operations which Lavoisier appropriated from PRIESTLEY, ‡ realized from WATT and CAVENDISH, § adopted from BLACK, adapted from GUYTON DE MORVEAU, eventuated from JEAN REY || and HALLESIIUS, ¶ affiliated from BOYLE, imitated from EHLMANN, &c., were compounded by the Paris Scientific Committee of 1788—De Morveau, Berthollet, Lavoisier, and De Fourcroy—into a chemical system, which is the

* Liebig ('Letters on Chemistry,' p. 102) gives to Richter the credit of this great discovery; but Richter went no further than drawing up a Table of the amount (by weight) of bases and acids required to saturate each other, and this not till 1792.

† Babbage, 'Decline of Science in England,' p. 12.

‡ "This species of air (oxygen) was discovered about the same time by Dr. Priestley and *myself*.—Lavoisier's 'Elements of Chemistry.'

§ "Other chemists, as Mr. Lavoisier at Paris, who has shamefully attempted to appropriate the discovery to himself, have now amply confirmed this unexpected observation" (the synthesis of water).—Note by the English translator to 'Bergman's Elective Attractions.' London: Murray. 1785. Page 344. Watt's discovery seems to have suggested that of Cavendish.

|| "Jean Rey, a physician of Perigord, attributed (in 1630) the increase of weight in calcined metals to the combination of air with the metal. . . . He reasons like a chemist of considerable skill, to prove that the increase of weight cannot be carried beyond a point of saturation."—'Chaptal's Elements of Chemistry,' Eng. trans. (by Nicholson). 1800.

¶ Whether "Hallesius" preceded Rey or not, I do not know, unless the former name represents Stephen Hales; but he seems to have had a very clear idea of pyrooxidation, so universally ascribed to Lavoisier. "*Metalla plurima calcinata incrementum ponderis in igne suscipere. . . . Causam hujus incrementi, alii cum R. Boyle et Hiernero ab igniculorum vel materiæ igneæ adhæsione deducunt; alii cum HALLESIO, ab accessu aëris, et ejusdem in solidum corpus mutatione.*" See Wallerius, 'Elementa Metallurgicæ.' Stockholm. 1768. Page 208. It is a most curious fact that this treatise of Wallerius, who is most industrious, candid, and copious in quoting his authorities, never mentions in its mineralogical part the "Essay" of Cronstedt, said (by Von Engestrom) to have been published ten years previously, although it cites Cronstedt's writings from the 'Acts of the R. Acad. of Sc. of Stockholm' for 1763. Berzelius (page 4) contradicts himself regarding the date of the *English translation*, which was in reality 1770. It seems reasonable to doubt if any edition of Cronstedt's Essay was published before the German "translation" of 1760 at Copenhagen.

virtual basis of the present one, although Frenchmen are in the habit of imputing the whole design to Lavoisier alone. The acuteness and industry indeed, shown by the last-mentioned chemist in the appropriation of others' labours, and in always associating himself experimentally with other scientific men—for his "Table of Specific Heats" was drawn up in conjunction with LAPLACE; his experiments in using an oxygen blowpipe with, and after ERHMANN; in "proving that, by the combustion of diamonds in closed vessels, the diamond did not burn, *but in proportion to the oxygen present*," with CADET; in volatilizing gold by a lens, with MACQUER; in "decomposing" water by hot zinc, with MEUSNIER; in measuring the dilatation of mercury, with BUCQUET; in determining phosphoric salts, with SAGE, &c.—seem deserving of the highest commendation; but these qualities of his mind could only have been exerted in the absence of originality and abstract morality. Even in these days of thought-prigging, fostered as that accomplishment is here by the confused codification of injustice based on technical quibbling and verbal hair-splitting, termed "English copyright and patent law," under which we have the happiness to live, the barefaced appropriations of Lavoisier quite startle one. He seems to have been a clever man utterly devoid of honourable principle, with about as much candour as a cat surprising mice; and it seems astonishing that, with such a character, *any* statement of his should have been taken upon trust. Yet we find it stated, with regard to the fusion of tin in a vessel containing a measured quantity of air, that, "more sagacious and skilful than his predecessor (Dr. Black!), Lavoisier was able to establish the fact that the increase in weight of the tin represents *exactly the weight of the air* which enters the vessel when it is opened after cooling." * This was in 1772, *before* oxygen had been discovered "by himself and Dr. Priestley about the same time;" *after* that most glorious and important event, Lavoisier changes his note, and entirely stultifies his first "precise and exact operations" by stating in a new paper, addressed to the Paris Academy, that "in the calcination of metals, and in combustion, it is *not the whole* of the air, but *one of its elements*, viz. oxygen, that is absorbed." † Neither the French eulogist of Lavoisier nor his English translator seems to have perceived the absurdity of this flat contradiction in proximate pages, and that one or other of the statements quoted must have been a deliberate falsehood.

Again, M. Wurtz says, "Lavoisier showed that this gas is one of the elements of air," whereas we find Bergman writing thus in 1774, ‡ "The atmo-

* Wurtz's 'History of Chemical Theories,' trans. by Dr. Watts. Page 14.

† *Ibid.* p. 15.

‡ 'Elective Attractions,' by Torbern Bergman. Eng. trans. Lond. 1785. Pages 198, 199. The preface says, "the dissertation was first published in 1775, in vol. iii. of the 'New Upsal Transactions.'"

sphere . . . is found to contain, besides vapours, . . . *three fluids mixed together*, and widely differing in their nature. . . . The greatest part, which certainly exceeds the others three times or more in bulk, is neither fit for supporting fire, nor for respiration. . . . That which in England is called 'dephlogistinated' or vital air, is *found but sparingly mixed with the atmosphere*, amounting scarcely to one-fourth of its bulk, seldom or never exceeding one-third," &c. And again, with reference to the so-called "reversing of Priestley's experiment by Lavoisier": "Mercury is well and quickly *calcined* in vital air, but remains unchanged in corrupted air, as Dr. Priestley *has found*." * Lavoisier, *after all this was done and known*, seems certainly to have first thought (probably in connection with Buequet) of oxidizing mercury by "placing the glass flask containing some in a sand bath, so that its temperature might be constantly maintained at about 660° Fahr. for several weeks."† Even the universally adopted and very erroneous term "oxygen" or acid-maker, seems to have been flashed up by Lavoisier from old medical works, for we find BOERHAAVE writing, about 1710, that "Hippocrates ordered nothing but *acids* or medicines tending to an *acid nature*, as *Oxygal*, for some distempers." ‡

It would be the height of presumption, in any lesser intellect than Newton's, Huxley's, or Haeckel's, to apply the term "absurd" to an idea which could satisfy such minds as those of Priestley, Cavendish, Scheele, and Bergman; yet the abstraction or phantom called "*Phlogiston*," conjured by Stahl,§ and finally "laid" by the Paris Committee, aided by De Morveau's excellent nomenclature, a hundred years after, in 1788, has such a grotesque side to it as to somewhat detract the respect and veneration with which Europe will ever remember those great men, who were the very reverse of mere theorists.

Stahl (unlike Pepper) seems to have started his "ghost" in a most original manner, thus: "If one-third part of charcoal and two-thirds of vitriolated tartar be mixed and fused in a crucible, the product is liver of sulphur. If this hepar be dissolved in water, and the alkali be engaged by adding a few drops of oil of vitriol, a residuum is afforded, which consists of true sulphur; whence the sulphur in a combination of phlogiston, or the inflammable principle of the charcoal with the oil of vitriol."|| Bergman describes phlogiston as "a very subtile matter, existing in two states: of combination and of freedom. In the former it enters into the structure of bodies, eludes our senses, and can only be recognized as its vehicle for which reason some have supposed it to be a fictitious substance;

* *Page 316.*

† 'Bloxam's Chemistry.' London: Churchill. 1867. Page 12.

‡ 'Boerhaave's Method of Chemistry.' Eng. trans. London: Longman. 1727. Page 575.

§ Wallerius, however, states ('Elementa Metallurgiæ,' p. 147) that both the idea and the term "Phlogiston" were conceived and applied by BOERHAEVE; and that "Stahl, Juncker, and other authors adopted that theory."

|| 'G. E. Stahl's Fundamenta Chimiciæ,' vol. ii. page 162.

but the two celebrated philosophers, Priestley and Kirwan, have clearly proved its existence, both analytically and synthetically. When this principle in combination recovers its elasticity, and gains an aerial form by a proper increase of specific heat, it receives the name of inflammable air. . . . A cubic decimal inch of inflammable air is equal in weight to $\frac{1}{1880}$ of an assay pound, and it contains as much phlogiston as two pounds of forged iron, i. e. $\frac{1}{1880}$; therefore $\frac{63 - 50}{1000} = \frac{13}{1000}$, give the weight of specific fire necessary to the aerial form.

I speak here of the inflammable air of metals; that which organic bodies yield appears to be less pure," &c.* The latter part of this quotation shows that Bergman, who, after Black, deserves the credit of applying the balance to the establishment of theories, had begun to render this abstraction susceptible, in the words of the old writers, "of the severest mathematical proof"; just as Descartes proved his vorticose vagaries of the planetary orbits;† or as Whately proved that Bonaparte never existed. This phlogistic theory however, strange as it now appears, lasted a century, that is, some thirty years longer than the present theory has lasted; a fact which should have the effect of making us more cautious and less dogmatic than many chemical authorities now are, for it should be remembered also that Davy, after discovering potassium, stated that he considered it contained an "inflammable principle."‡

We seem, indeed, to have copied the French chemical system, just as we copied their army system, and who can say what will be the state of the case "sixty years hence"? Will Nacquet, Roscoe, Odling, or Fownes, be purchasable in London (in three volumes) for sixpence, as I bought Chaptal's 'Elements of Chemistry' the other day? Even such writers as Davy, Turner, Thomson, Gregory, &c., are nowhere to-day, although the principles of chemistry have by no means changed since their time.

There can be no doubt of the proportional combination of some substances, dissolved in acid or alkaline solutions, having an indefinite quantity of water super-added—with others; but have we not been rather hasty in thence generalizing such a theory as that of atomic weights for all "elements"? Davy, the most trustworthy of chemists, seems to have doubted the fact of universal combining proportions, even as exemplified by hydracid analysis alone, going so far, as has been stated, as to consider the metal potassium "to contain an inflammable principle"; and we certainly cannot be sufficiently

* 'Bergman's Elective Attractions,' art. "Phlogiston," p. 219.

† Laplace, in mathematically accounting for the height of the tides by the laws of gravitation, stated that the average depth of the ocean *must* be *ten miles*. See Bakewell's 'Geology,' page 8.

‡ See 'Nicholson's Encyclopædia,' art. "Potassium." 1809.

careful in avoiding the danger of tabulating such an important (if true) abstraction as combining weights, upon the basis of what may, after all, turn out to be merely defective, or rather, *too coarse* analysis. Still greater is the danger of falling into the fascinating practice of "cooking,"* that is, of forcing natural phenomena to appear to coincide with a predetermined "law" or theory. This ingenious process of fitting the foot to the boot has, apparently, the strongest claims to French paternity, and M. Wurtz may fairly point to most of our modern chemical works to show how universally we have adopted it. "It is obvious that the atomic weights (*sic*) of an element, and of its combinations, *should be selected* so as to express the entire series of combinations by the simplest series of formulæ; so as *best* to accord with the chemical properties and metamorphoses of the bodies; so as *best* to illustrate the analogies with other bodies; and *so as to be in relation* with their physical properties, such as their sp. vols., sp. heats, isomorphism, &c. Now it so happens that these different requirements, chemical and physical, are not always satisfied by one and the same number. *Hence we have to subordinate requirements much in the same manner that zoologists and botanists subordinate characters.*"† So far from "subordinating characters," however, naturalists who are really worthy of the name, diligently search out and follow those, as the sole trustworthy guide in natural history. "The principle [divergence of character] which I have designated by this term, is of *high importance*. . . . As has always been my practice, I have *sought light* on this head from our domestic productions." And again, "In plants, the same gradual process of improvement *may be recognized*," &c.‡ In fact, instead of attempting to strap up Nature in demi-mathematical tabulations, or to "subordinate" her operations to Cuvierian or other systems, Mr. Darwin had recourse to *practical experiment* as the sole source of earthly knowledge; he "took up domestic pigeons"; he "associated with several eminent fanciers, and was permitted to join two of the London pigeon clubs"; and having thus, in the words of Bacon, "conquered Nature by obeying her," has produced a work which, to all appearance, will be immortal.

The presumption of attempting to doubt an "established" chemical or mathematical theory can be readily appreciated by contemporaries, but is not so easily understood when the indignation occasioned by such doubts is that of a former generation. In 1670, Becher wrote of alchemy: "Concludo enim, *pro thesi firmissima*, asinus est qui contra alchymiam loquitur, sed stultus et nebulo qui illam practicè venalem exponit."§ The unfortunate Dr. Robert Green, Fellow of Clare Hall, Cambridge, who, in 1712, had the sagacity and audacity

* See Paragraph (269).

† 'Origin of Species,' pp. 27, 86.

‡ Watts's 'Chemical Dictionary,' vol. i., p. 456.

§ 'Physica Subterranea,' lib. v. cap. iii.

to hit the one defect in Newton's optics, and to "show the unreasonableness of the greatest part of that philosophy hitherto received under the name of *Corpuscularian*," was treated with the following rap over the knuckles. "The celebrated Mr. Cotes* used to say that his (Green's) book showed the author to have had as extraordinary a genius as Sir I. Newton's, since it must have been the effect of design to guard so effectually as he did against saying *any one right thing* throughout so large a treatise."† It is indeed amusing, and yet also sad, to see the liberal manner in which the adjectives, "famous, celebrated, illustrious," &c., are applied in not very old books to phantoms who have long since disappeared from scientific memory, and "left not a wrack behind"; while others are remembered on the ocean of time, only to be laughed at, like the fireman of a China steamer, who, in a fit of delirium tremens, jumped overboard at sea, but when searched for by a boat, the only trace found of him was *a circular spot of dirty oil* on "the face of the troubled waters" where he had sunk!

It seems evident that besides Davy, Faraday and Dumas have both entertained doubts of the correctness of the present metallo-elemental theory; or, at any rate, believed in the possibility of transmutation. "The business of the Chemical Section (of the British Association) was opened on Friday, July 4, 1851, by Dr. Faraday, who read a communication from M. Bergeman, of Bonn, introducing a new metal which he called 'Donarium.' . . . Mr. Faraday said 'he was almost sorry to welcome any more metals; they fell on us like asteroids, and confused our reckonings; *his hopes were in the direction of proving that bodies called simple were really compounds*, and might be formed artificially, as soon as we were masters of the laws influencing their combination.' M. Dumas showed, at the same meeting, how readily the algebræo-chemical process may be applied to the doctrine of transmutation. 'If we could by any means cause the union of half an atom of chlorine with half an atom of iodine, we might hope to get—to form—to create—an atom of bromine!' Again, 'If by any means we could effect the union of half an atom of barium with half an atom of calcium, we should have as a resultant one atom of strontium. . . . That this symmetry of chemical with mathematical function points to the possibility of transmutation is unquestionable. . . . Chemists see no manifestations of a tendency of being able to convert lead into silver, or silver into gold. These metals are not chemically conformable; one cannot take the place of another by substitution: they do not form an isomeric group. The probability is, that our first successful transmutation as regards the metals will effect the change of physical state merely,‡ without touching chemical composition: thus, already we have carbon, which, as the diamond, and as charcoal, manifests two widely

* "Professor of Astronomy."

† 'Newtonian Philosophy,' vol. i., p. 142.

‡ Allotropy:—a masterly conception.

different states. Sulphur also assumes two forms, as also does phosphorus; then why not a metal?"*

Thus we see some of the most eminent chemists of this century expressing what must be characterized as beyond mere doubts with regard to the universal correctness of the present or French chemical theory, viz. that metals are *elements*, so created, which, on being molecularly modified in air by heat or other means, simply combine with the oxygen of that to form substances heavier, but far more bulky than those were. It must be admitted that this hypothesis, although based apparently upon defective, because incomplete analysis, has in every way the advantage of the phlogistic or "specific fire" delusion which it superseded; and further, that numerous and careful experiments show it to be to some extent true. That it is not *wholly* so, may be proved by *gently* heating,† before a pyrocone or blowpipe, small fragments of pure zinc, iron, lead, copper, potassium, aluminum, or any of the more easily decomposed metals, supported at the bottom of a bead of phosphoric acid, as shown in Fig. 65 of this work. The moment decomposition commences a strong smell of phosphoretted hydrogen (H_3P) is eliminated, which continues as long as the bead remains hot. This phenomenon is occasioned even by an *oxidating* pyrocone, a fact which disposes of any straw-catching argument as to the possibility of *both* constituents of the gas having been derived from the bead, or the hydrogen from the pyrocone itself. What alternative then remains for our consideration? A fact no less than this: *Hydrogen forms a component of most, if not of all metals.* Besides this gas (1), the following suggestive appearances *invariably* result from the decomposition of such metals in the above-described experiment; (2) a *black* gelatinous exudation; and (3) a *brick-red* matter, both easily observed in the cold bead like a fly in amber. The fact that these are the *invariable* products of such decomposition seems (to me) to dispose of the obvious objection that they are occasioned by accidental impurities.

If this metallic hydrogenous disengagement be—as it seems impossible to doubt—true, it follows that the hypothesis of the *exact* (by weight) *addition* of atmospheric oxygen to metals, oxidizing through the application of heat, is *not* true. If the latter allegation, however, be susceptible of proof, by the evidence of three careful experiments—though it must be remarked that the theorems educed so easily out of the comparatively clumsy operations and apparatus of Lavoisier and his coadjutors require, in order to afford sufficient proof to-day, the introduction of calcic chloride, hydric sulphate, or other moisture-abstracting reagent, not required by those chemists to produce *the same* results—it still remains to be said that atmospheric oxygen might exactly *replace* in weight the loss of gas or gases evolved by decomposition.

* 'Chemical Record,' 12th July, 1851.

† As described in Paragraph (129, b).

In the ordinary way of producing hydrogen gas, I placed a fragment of zinc in a graduated test tube containing a measured quantity of distilled water, acidulated with two drops of hydric sulphate, and by gentle heating obtained a considerable quantity of gas, with a proportionate diminution of *zinc*, but *none* perceptible of *water*: indeed, in all such operations the quantity of hydrogen obtainable is calculated entirely from the *loss of zinc*, although it is supposed to proceed entirely from the solution of hydric sulphate, and the experiment above recorded, of the unmistakable smell of phosphoretted *hydrogen* evolved by the same metal, seems to me to prove beyond all doubt that hydrogen is generated in both cases from the decomposition of the *zinc*, and not of the solution or flux surrounding it. If hydrogen then be supposed (as I maintain we have considerable ground for supposing it) to be, not a metal itself, as many chemists assert, but *the metallic principle of all metals*, we should have a new and most interesting key with which to attempt to unlock the yet unexplained secrets of electricity, magnetism, and some spectral phenomena; but the details of such an argument, many of which I collected in 1870, in India, are too numerous to be inserted here.

On the accepted hypothesis that metallic action on solutions evolves any liberated hydrogen from those, we must submit, in some cases, to a flat contradiction in terms, involving a mathematical absurdity. This fact has not escaped the keen observation of Mr. Grove, who has done so much for experimental science. "I find that if a substance capable of supporting an intense heat, and incapable of being acted upon by water or either of its elements—such, for instance, as platinum or iridium—be raised to a high point of ignition and then immersed in water, bubbles of permanent gas ascend from it, which on examination are found to consist of mixed oxygen and hydrogen in the proportions in which they form water. . . . Now, when mixed oxygen and hydrogen are exposed to a temperature of about 800°, they combine and form water; heat therefore appears to act differently upon these elements according to its intensity, in the one case producing composition, in the other decomposition. No satisfactory means of reconciling this apparent anomaly have been pointed out." * The student of pyrology will find, at pp. 5, 6, of this work, an experiment with platinum and *boric acid* curiously analogous to the above, which seems to avoid the contradictory difficulty by the assumption that the gases produced are evolved by the action of a *sufficient surface* of heated platinum, *upon the air*, and the invisible steam it contains.

To sum up the matter, I submit that, instead of laying down a table of atomic weights derived from hydracid analysis alone, still less from secondary

* 'Correlation of Physical Forces,' p. 81.

mathematical calculations depending upon that, we should ascertain the combining proportion of each separate substance *experimentally* separated in three ways, as (1) by means of hydracid solutions; (2) through the operation of pyrological acids; and (3) by galvanic reagency. If, under the operation of these different influences, a substance, disengaged from any compound, unites in the same, or in a multiple proportion with other substances, we may unhesitatingly adopt that as the combining proportion of that substance in terms (say) of an atom of hydrogen = 1. This may seem an enormous labour for chemists and philosophers interested in the question; but is it not better that the chemists of this age should incur such a labour, than that a "theory" only partly established should be swept away, and perhaps even laughed at by those of the next?

There seems, indeed, strong reason to doubt the correctness of the tabulated combining weights of several of the so-called "elements" in modern chemical works. Up to the year 1820, the mineral *Wavellite* was supposed to be essentially a hydrous oxide of aluminum, containing 70 per cent. of alumina, as determined by the careful analysts Klaproth, Davy, and Berzelius. In that year, however, Berzelius himself suddenly discovered *with the blowpipe* that the mineral was a *phosphate* of aluminum; and what followed? Simply this, that although essentially the same reagents for the determination of alumina are used by analysts from Thenard (1817) to Noad (1870), the atomic weight of aluminum ($H = 1$) was *suddenly changed* from 9 to 13.7—it is now 27.5—and of phosphorus from 12 to 31. The "requirements" of Nature had been in fact "subordinated" to coincide with human systems. In 1823, as is evident from Phillips's 'Mineralogy,' the chemists had not detected the phosphatic nature of *Lazulite*. To take a more modern instance. We have (1875) the atomic weight of *Cerium* tabulated (as it was by Berzelius) 92, and *Didymium* 96; but if we take "pure *Ceric* oxide," as separated by the best chemical analysts in England, Germany, or France, heat a few specks of it on a bead of boric acid before a pyrogene or blowpipe until a red-brown ball is formed inside the bead, and examine this ball by transmitted light with a *spectrum lorgnette*, the *didymic* spectral lines or absorption bands are perceived quite strongly. It is, in fact, evident that the chemists have never succeeded in separating these two substances; by what Lavoisierian process therefore they have ascertained the atomic weight of each so precisely, it is not difficult to conjecture. As for the algebric minerals with which most modern works on mineralogy bristle, those formulæ, for the most part, cannot be considered otherwise than solemn impostures; impostures, because 999 of each 1000 do not represent the actual composition of the mineral; constituents being often almost blasphemously—considering to WHOM we are dictating—said to be "present as an *impurity*" (!). Solemn, because those who drew them up really believed each to represent the hypothetically "pure" mineral. These mineralistic formulæ are, however,

useful for the purpose of indicating at a glance the nature of the principal constituents.

In short, the more the matter is investigated, the greater seems the certainty that *practical experiment*, with a strict "*obedience to Nature*" in the attempted solution of the arising problems, is the only real source of earthly knowledge, and I submit that the former cannot be applied, nor the latter exacted, in a more delightful, elegant, or important way than by the almost unused modes of analysis, which the proficient will, I fear, find but feebly set forth in the following pages; but in soliciting some consideration on his part towards what I have been writing for three and studying for fifteen years, I would ask him to remember that I have been *absolutely alone* in making researches, chiefly in an out-of-the-way place like India, of an entirely novel character, and that I had not, and could not have, even a book "wherewith to guide my feeble hands." But the field thus inefficiently opened to the general philosopher as well as to the scientist of almost every branch of knowledge, and the artist in almost every art, seems of illimitable extent, the visible part of which will probably, before long, be occupied by abler pioneers than myself with amazing rapidity, for I find that, even in the time which has elapsed since this work went to press, I have thought of matters which have been too carelessly omitted from its pages. For instance, that *Aluminum*, which I have found fusible (or, rather, to "droop," as the gunners call it) before the pyrogene in the inverse proportion to its *bulk*, would thus form an excellent *pyrometer*; as it will no doubt, from its extreme lightness, be most useful in the *quantitative* determination of sublimates. That the beautiful orange-red light obtained from *lime* without decreasing the weight of this, described at pages 60, 126 of this work, could probably be cheaply made permanent, and at the same time splendidly luminous, by simply placing the fragment of lime in an electric arc synchronously with its emission. That a charming violet or "lake" *pigment* is obtained by simply heating before the pyrogene, cobalt oxide in about ten times its weight of boric acid, extracting the violet ball formed, with boiling water, and grinding it to fine powder. That glass could be probably colored with a violet tint superior in beauty to that of the "purple of Cassius" by fusing silica with cobalt protoxide and a *very small* proportion of soda or potash, in the "flame" of an oxyhydrogen blowpipe. That *tin* fused on aluminum plate, and suddenly quenched with cold water, becomes as tough as zinc, while it retains its malleability and beautiful whiteness, &c. I am so sanguine as to hope, in fact, that there is matter in this book for twenty patents, and had I lived under any other than the English patent law, which recognizes unprincipled "improvements" rather than original inventions, I would, in justice to my own family, have patented many of them. A still more unjust and, in fact, a disreputable English law, is that which *exacts* FIVE copies of the most expensive work from an author, *gratis*, without pretending to afford him, in

return, the *protection* of the law, as the admirable *Code Napoléon*, for the *voluntary presentation* of two copies, does to a French or other author publishing in France. We are not, I believe, a poverty-stricken nation, but if we were, the forcible removal of a loaf of bread is not considered honest, even on the part of a starving person. As regards my own case, I intend to *present* copies of this work to the British Museum, and to the library of Cambridge, because I have received assistance from Professors Stokes, Miller, and Maskelyne; but if the secretary of any other public library receives a copy without paying for it, he obtains it against my consent, and must cheerfully accept the denomination applied, in spite of English law, to those persons who take possession of other people's property by force. I have received no benefit whatever from any public library, having had not merely to purchase, but to carry about through India, most of the books I was compelled to consult,* and I really do not see why I should be made to gratuitously support any.

I now commit this work, which has, at intervals, occupied so many years of my life, to whatever appreciation may be shown to it by scientific and practical men; but I must confess a secret wish and hope that the direction in which my efforts have been exerted may be favourably recognized in Germany and America, because those nations seem to take more interest in the matter than others. Whenever I communicated a new result in England (except to the eminent men above mentioned), I was invariably *asked*, in *answer*, "WILL IT PAY?" Disgusted and yet amused at first, I am now convinced that this is sound policy on the part of the English, and has probably preserved them, in spite of all the so-called "decline of science" here, in spite of all our abominable patent and copyright laws, in the high scientific position they still occupy in Europe. A pity it is, indeed, that the same practical principle has not yet extended to India, "*forty millions of pounds*, collected from the taxpayers of which country" during the last ten years, could be absolutely *wasted* in building barracks, &c., with "rotten," mortar, without raising a note of indignation against the late il-"liberal" Government, who managed to evade the apathetic scrutiny of Parliament by getting the whole matter shelved "in Committee," so that, besides having been taxed for nothing, we must, in that quarter, bear as we may the insults and laughter of other nations; the Russian officers in Bokhara having, as I am informed, even composed a song about us, of which the *refrain* is—

"The tumble-down Barracks of Ind!"

It may be necessary to state here that any roughness in the plates or diagrams must be attributed to myself, who designed and drew them, and not to the lithographer, who has faithfully copied my drawings.

MIDFEARN, SHEPHERD'S BUSH, LONDON, W.

May 11, 1875.

W. A. ROSS.

* One error arising from this source is the attribution (at page 18) to Bergman, instead of to Black, of the discovery of carbonic acid gas.

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EXPLANATION OF TERMS AND SYMBOLS USED IN THE INTRODUCTION TO
THIS WORK.

Pyrocone—A flame having a conical shape.

Pyrochrome—A non-luminous flame tinged with color.

Pyrogene—The instrument by means of which pyrocones are *generated*:—
a chemist's blowpipe.

$\ddot{\text{H}}\text{B}$ —Fused boric acid.

$\ddot{\text{H}}\text{P}$ —Fused phosphoric acid.

H.P.—Hydrocarbonous pyrocone, Paragraph (86).

O.P.—Oxyhydrogen pyrocone, „ (87).

P.P.—Peroxydizing pyrocone, „ (88).

E.P.—Ellychnine pyrocone, „ (91).

Essay—A qualitative or indicating examination.

Assay—A quantitative or determining examination.

[These words also express the *subjects* of such examination.]

Crystallignation—The crystallization of substances cooling from fusion by
the direct application of fire.

A Bead—The *largest* amount of flux fusible on a platinum wire ring of
given diameter.

A Glass—The *smallest* amount of flux fusible on a platinum wire ring of
given diameter.

PYROLOGY, OR FIRE CHEMISTRY.

INTRODUCTION.

(1). THE analysis and synthesis of things is, next to religion, the most important subject which can occupy the human mind. It is, in fact, the investigation of material TRUTH, with such aids as the GREAT CREATOR has vouchsafed us. It is not necessary, in order to stimulate the peculiar action of the brain required for this purpose, that the subject of analysis should be material. Precisely the same operations of the mind are necessary to analyze a murder or a miracle, as a mineral; a military adversary's plan of campaign, as a calcic silicate; only, in the first, or incorporeal cases, the analyst and synthesist generally has some recognized facts as clues, upon which to proceed; in the second, no fact is given, beyond the existence of a material compound substance. The General, the Detective, or the Logician, deduces probabilities from facts: the Chemist, the Spectroscopist, the Physicist, or the Pyrologist, has first to *elicit* facts (which he calls "reactions"), from which, also, probabilities are concluded. The advantage thus, although at first sight the contrary is apparent, is on the side of the analyzer of incorporeal cases, for he has his facts ready made, whereas the other, in producing his facts by means of reagents, is liable to be led into a thousand errors or *suppositious* facts, and finally, to make such erroneous conclusions from undeniable facts, as will lead him more astray than if those facts had been primarily absent.

(2). Chemical analysis by means of acid and alkaline solutions, or what is usually called the "wet way," is a laborious, unwholesome, and, to be at all exact, difficult process. Besides, it presupposes the possession of a laboratory (which ought to be built for the purpose) full of expensive and in many cases unportable acids, alkaline solutions, and reagents. Since the delicate revelations by the spectroscope, also, have led scientific inquirers to unwarrantably pry into such things as the composition of cigar ashes and what not, whispers as to the absolute correctness of the results of "wet" analysis have been more than put forward. Sodium, lithium, potassium, and even calcium, strontium, and didymium, have been detected by the Spectroscopist in ultimate results of analysis, or in reagents, "where," in the words of the old song, "nae such things

should be." The grindings, filterings, edulcorations, desiccations, burning up with blotting-paper filters, &c., are averred to be like so much friction, taking away from the theoretical or mathematical correctness of the machine; while a precipitate (they say) sometimes savours of its precipitant, which, of course, it ought by no means to do, and this is certainly the case in some instances, as in the detection of Potash in "pure" Lanthana and Yttria.

(3). The chemists, on the other hand, although they admit the extreme delicacy of the Spectrognostic revelation of such substances as afford unmistakable spectral lines, when those are burned, affirm that the very delicacy of this mode of examination militates against its practical utility. "What does it matter" (say they) "if a man is in reality smoking a certain infinitesimal quantity of lithia and lime, if he tastes only tobacco?"—if a chemical result shows spectroscopically and strongly the presence of soda, when it has given to a nicety the chemical equivalent of *potash**?—if reagents are spectroscopically impure, when chemically, they answer the purpose for which they are intended?

(4). But there is, apparently, a more serious charge than this to bring against spectrum analysis; one which, if not disproved, must considerably shake our confidence in the accuracy of its results as now described. It is, that conclusions are drawn and set forth as facts, from the burning of substances in *atmospheric air*, and in the electric arc, as though electricity and air were *vacua*, and could not possibly combine with, or affect the result of the combustion. For instance, let us examine the hypothesis offered from the experiment of burning metallic sodium in the electric arc in air, as a proof that the absorption lines "D" of the solar spectrum are due to *sodium*. SCHELLEN says (p. 213), "As soon as the electric current passes, the sodium begins to glow strongly, and a single band of brilliant yellow about two inches wide is seen upon the screen, which is the spectrum of the luminous sodium vapour. But in a few seconds, a sharply-defined deep black line about an inch wide appears in the middle of this yellow band while the remaining portion of the color fades away. The bright yellow sodium line has become changed into a dark line which continues as long as the combustion of the sodium lasts. In this case the reversal is easily explained in the following manner. The sodium becomes first intensely heated, and its vapour emits its yellow light; immediately afterwards, a great portion of the sodium is converted into vapour by the great heat of the electric arc, and *envelopes the small luminous portion about the sodium in a dense cloud of non-luminous sodium vapour.*† The yellow light of the small luminous portion

* The reason for not orthodoxically calling these substances "sodium" and "potassium," will be shortly found.

† These are Dr. Schellen's italics.

of the sodium vapour must pass through this large cloud of sodium vapour of a lower temperature, and is absorbed by it before reaching the slit of the lamp. We may repeat the conclusive inference. *The vapour of sodium absorbs precisely the same light that luminous sodium vapour emits.*"

(5). The critical reader of the account of this phenomenon, attributed so exclusively to burning sodium and its vapour, with the "inference" so conclusively drawn, would at least suppose that the operators had taken the most absolute precautions to prevent the possibility of *anything but* the vapour of burning sodium exhibiting its spectrum; but this is not the case, for, waiving for the present the question of the introduction of electricity, of the nature of which we are entirely ignorant, the atmosphere, loaded as it always is at low elevations with invisible steam, is recklessly admitted to the subject of this experiment, and its attractions as unaccountably ignored: while the "cool" enveloping vapour, which causes the replacement of the yellow (orange?) line by the black or dark one, can be proved beyond reasonable doubt, by the chemist, to consist, not of vaporized sodium, but of *sodic hydrate*, and as "the relation between the power of emission and the power of absorption of one and the same class of rays is the same for all bodies at the same temperature,"* that is, as the faculty a luminous vapour possesses, of stopping the identical rays which it emits, is a fact apparently beyond controversion, it follows that the *orange* lines D of the "sodium" spectrum, given in the first instance, are not caused by the luminous vapour of metallic sodium, but by that of *sodic hydrate*.

(6). Another popular experiment, detailed as showing the universal presence of the element sodium, describes the touch of our fingers communicating its spectrum to that of new platinum wire, which, previous to the touch, had afforded when heated before the blowpipe a continuous spectrum, but after it, one showing the orange lines D. This is certainly true; but it is also true that a *new wire untouched* will also, for a moment, give an orange pyrochrome, exhibiting a spectrum with the "D" lines, and although this almost immediately vanishes, the same wire held in forceps, laid on an agate slab, without touching that or the fingers, or anything, will be found in the course of a quarter of an hour or so to *again* afford a spectrum containing the lines "D," while a platinum wire held in a moderately hot flame, as that of a spirit lamp, or the blue part of a gas one, uninterruptedly emits the orange pyrochrome.

(7). It does not seem to have struck the experimenters in the above-mentioned case, that *the duration of the D-line spectrum is in direct ratio to the thickness or substance of the platinum wire, and in inverse ratio to the amount of heat applied*; so that, if we use platinum of *certain thickness*, say new platinum

* Kirchoff, cited by Schellen.

tongs, and apply to it a certain amount of heat, as that given by a pyrogene or "blowpipe," we find that the orange pyrochrome is *permanent* and cannot be driven off by the same amount of heat, so that, unless sodium be supposed to be derived in some unaccountable manner from the fingers holding the other or brass end of the forceps, or from the pyrocone or "flame" itself, or to exist *per se* in the platinum over a certain thickness, and heated to a certain extent, it seems utterly impossible to ascribe the orange pyrochrome or the D-lines in this case to the presence of sodium.

(8). If we fuse a bead of common salt on a platinum wire, ringed at one end, and hold the other end in a forceps along with two pieces of moistened test paper, red and blue, a thick smoke arises, which is usually stated to be volatilized sodium chloride; but that would not, as this does, turn the blue paper red, for the former is neutral to test papers, while the smoke vapour has evidently an acid reaction; and if the tongue be applied to the bead it will be "nipped," showing the presence of a caustic alkali. Now, if a spirit lamp, which had previously afforded a blue flame, be held in this "smoke," the outer cone of the flame will be tinged with a deep-toned orange, and the same tint will be given to it by holding it over fuming hydrochloric acid. It seems undeniable, therefore, that in this experiment it is the *acid* component, and not the *alkaline base* which affords the D-line spectrum.

(9). Let us now fuse a bead of *Boric Acid* upon the ring of a platinum wire, and, taking upon it, while still hot, a fragment of metallic sodium half its size, freshly removed from its bottle of naphtha, rapidly plunge both into the middle of a pure *blue* pyrocone formed from a Berzelius "blowpipe" lamp, fed with pure cocoa-nut oil, or from one of my pyrological candles; we find (*a*) the sodium does not at once ignite, unless some atmospheric air gets to it (which, however, it will generally do in a pyrocone of such small dimensions); and (*β*), there is scarcely a tint of *orange* communicated to the blue color of the pyrocone, while the sodium is converted into a black mass, which becomes white by exposure to atmospheric air.

(10). We have therefore (*a*) § (5) *Sodic hydrate* affording the lines D.

" " " (*b*) § (7) *Metallic platinum* " " "
 " " " (*c*) § (8) *Fuming hydrochloric acid* " " "

and finally (*d*) *Metallic sodium*, not affording them. It seems impossible to me, after considering these proofs, to believe that the lines D of the solar spectrum are due, as is generally supposed, to the presence in his photosphere of *sodium* vapour.

(11). But if these lines are not due to sodium, to what are they due? The orange "flame" which exhibits them attends the combustion, not only as is

generally stated by the spectroscopist, of "most" but of *all* inorganic substances; those only excepted which have colored rays of their own strong enough to *overpower* the orange ones; as pure potash, lithia, strontia, and a few others. If, however, we support these substances on another, which, under the stimulus of sufficient heat, is able to decompose them by the attraction it possesses for the bases yielding the colored rays, we shall find these latter wholly or nearly suppressed, and an *orange* pyrochrome exhibited alone.*

(12). Such a substance is *Boric Acid*, and it seems advisable here to anticipate some remarks on this extraordinary and, for pyrological purposes, invaluable substance, when afterwards describing it as a reagent. In heating the crystallized acid (hydric borate) on a platinum ring before the pyrogene, it is observed to swell greatly and unroll its particles from the inside of the mass in the very peculiar manner which seems common only to it and some of the "Zeolites," as the mineral *Apophyllite*. This is evidently caused by the gradual elimination of its crystallization *water*, during the departure of which the pyrochrome given by an O.P. is at first pea-green, then a yellowish orange, which may afford to the spectroscopist Fraunhofer's D-lines. No sooner, however, is this last *water* gone than the pyrochrome is a yellowish *green*, and remains so until the whole is consumed.

(13). This fact, taken in connection with those detailed in (10), leads the observer to conclude that the orange pyrochrome *might* be due to water, as was supposed, on account of the universality with which burning substances emit it, by Fox Talbot in 1834. In such a conclusion he is opposed at the very outset of his investigations, by the fact related by chemists, that sodic chloride, which emits, when heated, an intensely orange pyrochrome, contains no water. If he be not daunted by this assertion, however, but pursue his researches in this direction, he will, I submit, find the weight of evidence practically obtained, going to show that *Na Cl* does in fact contain water, while on the other hand, no proof whatever of its being anhydrous is offered in the manuals of chemistry published in English, but the assertion is merely parenthetically made in those, as though it were an axiomatic fact.

(14). The curious fact stated in (7), that pieces of platinum over a certain *size* never cease, when heated, to emit the orange pyrochrome, seems in accordance with the better known fact of the property possessed by metallic platinum when strongly heated, of causing or at least facilitating the chemical combination of hydrogen with atmospheric oxygen about its surface, and it seemed therefore desirable to see if the combination of these gases (which I believed to be chemical water) could not be retained for examination, by *boric acid*, which substance I had

* Vide Paragraph (18).

already found when vesiculated* to be extremely sensitive to the contact of hygroscopic moisture from the breath.

(15). Boric acid indeed, fused on a platinum *wire*, produces a bead, clear and refractive as a diamond, and there is not the faintest trace in it of the introduction of any foreign substance; but then it will be remembered § (7), that the orange pyrochrome of the *wire* is not sufficiently permanent to affect the boric acid; so, instead of using a wire, I fused some perfectly pure crystallized boric acid (with which I had previously made clear beads on Pt. wire), in a new, clean platinum *spoon* of considerable thickness, and then made a bead on a new wire with the acid thus fused: the bead was *dull, opaline, and nearly opaque*; precisely the appearance bestowed on it by fusion in the bead, of *hydrated* or uncalcined lime!†

(16). We have now another and important fact to add to those collected in (10). It is this: the "D-lines" spectrum, afforded by heating new, clean, metallic platinum, is apparently due to the combustion of some combination of hydrogen with oxygen on its surface, and this combination or reaction, which is retained in boric acid, gives precisely the same appearance to the latter, which pure calcic *hydrate* gives, and which dehydrated or caustic lime does *not* give. It only remained, therefore, to see if this opalescence, communicated to boric acid by a large surface of heated platinum and also by calcic hydrate, could by any possibility be due to the *lime* in the latter case, and not to the water with which it was combined.

(17). To prove this, I weighed a clear ball‡ (which *calcined* lime always forms within a boric acid bead when treated with O.P.) of anhydrous calcic borate, and found its weight to be 22·9 mgrs. *Three* times in succession I extracted this ball, by boiling water in which it is utterly insoluble, from the bead, and applied it, under O.P., to three fresh beads of boric acid, after extraction from the last of which, it still weighed exactly 22·9 mgrs. The opalescence therefore, caused by the pyrological addition to boric acid of calcic hydrate, is due to its *water* and not to its lime.

(18). If the fact, then, of the opalescence caused to boric acid by calcic *hydrates* under heat, be admitted (as indeed can scarcely be reasonably denied) to be due to chemical water, we cannot fail to connect this water with the orange pyrochrome exhibiting one at any rate (the left-hand one towards the Red) of the D-lines, as follows: On taking up with the bottom of a red-hot bead of boric acid, a largish fragment of lime hydrate, and directing *on the latter alone*

* For an account of "vesiculation," see Paragraph (63) and Fig. 64.

† A whole ounce of pure crystallized acid was thus rendered opaque by simple fusion in a new platinum crucible.

‡ For an account of the formation of such "balls," see Paragraph (65).

a strong O.P., we obtain an intense *orange* pyrochrome, without, however, the least tinge of free *red*; as this leaves the mineral, it begins to glow brightly; the *whiter* it glows, the fainter becomes the orange pyrochrome; and the case is almost exactly the same with new platinum wire. The moment the mineral emits a *white* light, and not a moment before, it is taken up by the hot boric acid, where it forms a clear refractive ball, hard enough to scratch glass, giving to the bead a few streaks of opaline matter; but if it be taken up as a *hydrate* (which may be effected by directing a weak O.P. on the top of the *bead*, and keeping it carefully clear of the fragment of lime), the bead is almost opaque with opaline matter, but the ball in both cases will be found to contain exactly the same proportion of lime, or $\frac{W}{4.5}$ gives within .2 of the quantity of calcined lime used; where W = the weight of the lime-borate ball.

(19). The Boric acid bead, saturated with this chemical water, whether derived from a large surface of red-hot platinum or from lime hydrate, is *clear* and transparent while *hot*, but becomes *opaque* and white on cooling. The case is precisely the same with beads, either of *sodic* carbonate or chloride of sodium, but if these salts are added to a Boric acid bead, no opaline matter is given off, although (on my hypothesis) a quantity of chemical water is added to the bead. The reason is evident: the base of the salt (sodium), refusing to part with its water as lime does, is dissolved in the Boric acid *as a hydrate*, where it continues, as in borax, to have an *alkaline* effect on substances fluxed in it, as, e.g. on *Silica*, which is utterly infusible in boric acid, but is fluxed as rapidly by borax as by soda itself, and this seems proved by the hydrated (or pink) appearance of *Cobalt oxide* in Boric acid, rendered just fluid enough to dissolve the oxide, and no more, by a *very small* addition of soda. Such a bead is *blue* while very hot; for the boric acid under such a strain seems to make use of all the water (which fused boric acid shall shortly, by means of magnesia, be proved to possess) it has at command, its molecular nature apparently undergoing a change like that of silicic hydrate by extra heat, leaving the cobalt oxide *blue* and anhydrous: in cooling, the cobalt, which has a great attraction for water as shall also be shortly seen, gradually resumes this water from the boric acid, and the bead therefore gradually becomes *pink*. Now what happens if enough soda is added to give the bead an alkaline effect in fluxing substances? The bead *remains blue* on cooling, for the sodium has appropriated all the available water.

(20). The following, however, is a means of obtaining the opaline reaction in boric acid which I ascribe to chemical water, from *Sodic chloride*. If we apply the pure anhydrous lime-borate ball, obtained as described in (17), to pure fresh boric acid under O.P., there is of course no opaline matter given off, and

the clear refractive ball floats in the transparent bead in a very beautiful manner, whence it may be extracted intact and unaltered by boiling, as it is quite insoluble. If, however, we fuse it with the *smallest particle* of common salt in a platinum spoon, and *then* apply it to a boric acid bead, copious volumes of opaline matter are given off, which render the bead clear *hot*, but nearly opaque and white cold. A similar effect is produced by sodic hydrate or carbonate.

(21). That fused boric acid, or "anhydride" as it is now called, contains a certain amount of water (after it has lost that of crystallization), which seems necessary to its chemical constitution, as it remains clear hot and cold, may be proved by the following pretty experiment. Calcine a small fragment of Magnesian carbonate in a platinum hook* until it glows white hot: apply it to the bottom of a red-hot bead of boric acid, and direct an O.P. on the fragment, which will be seen, in spite of the calcination it has undergone, to emit an orange pyrochrome, glowing more brightly as that leaves it. The fragment is *then* taken up by the bead with a slight effervescence, and, through a lens, will be found in it, in the shape of a white (if the magnesia is perfectly pure) *opaque* ball like a miniature snowball; no opaline matter having been given off. After a strong O.P., however, directed as much as possible upon this ball, the bead being turned over and over for this purpose, the opaque ball will, with a slight gleam of phosphorescent light, suddenly become transparent, when it cannot be distinguished from the lime ball, and, like it, will be found *now* to have given off opaline matter; but, on the addition to the containing bead of a trace of fresh fused boric acid, the ball as suddenly becomes *opaque again*, evidently with "chemical water" derived from the fresh boric acid, while this is thereby rendered much less soluble in boiling water.

(22). If the hypothesis of the opacity being caused by water be reasonable, it would follow that the opaque ball is *lighter* than the transparent one (although to superficial observation, the contrary seems likely), because the ball has in fact exchanged water (H_2O mol. wt. = 18) for (B_2O_3 mol. wt. = 70); and this is the case. There seems also, to me, another almost conclusive proof that constitutional water has been abstracted by the *ball*, rendered opaque from the *bead*, in the fact, quite to have been expected, that this dehydrated bead is much *less soluble* in boiling water than ordinary fused boric acid is; and, indeed, it seems an axiom in these pyrological experiments, that *the less chemical water a substance contains, the less soluble it is, either in water or in fluxes, under heat*.

(23). Magnesia *retains* chemical water under greater heat than lime does, and after it has been dehydrated shows more attraction for it than the latter in

* For a description of this, see art. *Matériel*, Paragraph (102).

similar circumstances. It is on this account that the former earth requires so much more continued O.P. to clarify the opaque white ball it has formed in boric acid than lime, that the magnesian clear ball becomes, unlike that of lime, opaque again by the addition of fresh fused boric acid, and that magnesia, saturated with cobalt solution, affords the well-known test of remaining *pink* (or hydrated) under the strongest heat of the pyrogene. When a fragment of this earth, treated with O.P. at the bottom of a boric acid bead (21) is emitting its orange "flame," this ceases so exactly when the fragment has evidently become white and caustic from loss of water, that the observer is struck with a feeling of surprise that he should have ever attributed this orange "flame" to sodium, or, indeed, to anything but chemical water.

(24). This must not be confounded with water of crystallization and hygroscopic water, which, so far from burning with any demonstrative tint, appear to increase the brilliancy of pyrochromatic *bases* (12), while chemical water either very much modifies or totally overpowers the strongest pyrochrome; and it is on this account that sodium has been supposed to exist in almost every earthly substance and gas, when in reality it is *water* which exists in them. Besides differing from the ordinary water of salts and oxides expellable by mere heat, in the phenomenon of burning, chemical water can be distinguished from that by its *smell* and *taste*, both of which are very peculiar and may be ascertained in the following way:

(25). Crystallized boric acid when heated smokes strongly, and this smoke, which appears to be steam loaded with an otherwise invisible sublimate* of the acid, has a pleasant, soothing, aromatic smell; after it has been *platinized*, however (15), or made opaline with the chemical water communicated to it, the smell on first heating it, as by plunging a red-hot bead in it, is *completely different*, and is *now* sharp, peculiar, and disagreeable (to me), something like that of burning resin. I should not have considered this change of smell, unaccountable as it otherwise is, sufficient proof that the change was due to the chemical water undeniably introduced, had I not found that "glacial" *phosphoric acid*, which has also a strong and not unpleasant smell when heated, quite different from that of boric acid, also acquires a *completely changed* odor by being fused in a platinum crucible or saucer, and—what appeared to me conclusive—that the *platinized* phosphoric acid had, when momentarily heated, precisely the same disagreeable smell of burning resin that platinized boric acid acquires.

(26). Let us now therefore suppose, with Fox Talbot, that this universal orange pyrochrome, exhibiting the D-lines, is due to *water*, instead of, with

* This sublimate may, however, be retained by pressing a red-hot boric acid bead upon a *smaller* fragment of the cold acid, upon clean shining aluminum foil, when a white sublimate is obtained round the latter.

Kirchoff, Mitscherlich, and others, that it is due to *sodium*; how simple and natural the otherwise startling facts appear! Instead of supposing that the air is so loaded with chloride of sodium, that the opening of an umbrella in a room causes its spectrum to appear; that we ourselves are so saturated with the same substance, that our merest touch communicates it, representing us as almost saturated with salt, we suppose that this omnipresent substance is *water*. There is nothing unnatural in this. We know that the air *is* loaded with it, and that it forms two-thirds of the flesh of our bodies. We know that it is a product of combustion, and I submit that I have here given reasonable proof that it can be burned.

(27). If the decomposition of sodic chloride by heat (which certainly takes place (8)) be attributed to the attraction of the separating chlorine for the hydrogen of the water of the salt (assuming it to contain water), we should have an apparently reasonable explanation of the undoubtedly acid smoke which fills the room and tinges the blue spirit-lamp flame with orange, in the hypothesis that the hydrochloric acid gas formed (itself transparent) absorbs and condenses the atmospheric moisture so as to become visible as vapour, and to tinge all blue flame with orange.

(28). If, again, we suppose the lines D of Fraunhofer's spectral map to be due to water, it naturally follows that a hypothetical line in the *pure* red would be the simple spectrum of *hydrogen*, not the gas, which cannot be assumed to be elementary hydrogen; that the spectrum of oxygen or *ozone*, is represented by a hypothetical line in the pure *yellow*, and of carbon by one in the pure *blue*. And from this again it follows that the various spectra in the orange, green, violet, indigo, &c., are due to the vapour of substances composed of combinations of these elements, and thus that such lines seen in the solar spectrum should scarcely without further evidence, be—as they now generally are—attributed to the vapour of burning terrestrial metals in the solar photosphere, but that our metals should rather be supposed to be composed of these three elements in different proportions, and there seems nothing extravagant in such a supposition, when we consider that the most perfect organization in creation, the human frame, is composed of these very elements, and nitrogen: further, it seems a retrograde step in our reverential admiration of Omnipotence to believe that it was *necessary* for each metal to be a separate element especially created.

(29). These statements may be considered unlikely, problematical, vague, absurd, preposterous, "phlogistical," or any other adjective which the learning or modesty of the critic may induce him to apply to them; all I say is, that they would not have been advanced here if there had not been facts to adduce in support of them. The facts are these: Small fragments of metals as pure as I

similar circumstances. It is on this account that the former earth requires so much more continued O.P. to clarify the opaque white ball it has formed in boric acid than lime, that the magnesian clear ball becomes, unlike that of lime, opaque again by the addition of fresh fused boric acid, and that magnesia, saturated with cobalt solution, affords the well-known test of remaining *pink* (or hydrated) under the strongest heat of the pyrogene. When a fragment of this earth, treated with O.P. at the bottom of a boric acid bead (21) is emitting its orange "flame," this ceases so exactly when the fragment has evidently become white and caustic from loss of water, that the observer is struck with a feeling of surprise that he should have ever attributed this orange "flame" to sodium, or, indeed, to anything but chemical water.

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(26). Let us now therefore suppose, with Fox Talbot, that this universal orange pyrochrome, exhibiting the D-lines, is due to *water*, instead of, with

* This sublimate may, however, be retained by pressing a red-hot boric acid bead upon a *smaller* fragment of the cold acid, upon clean shining aluminum foil, when a white sublimate is obtained round the latter.

(32). It seems indeed almost marvellous, that such a simple, cheap, rapid, and accurate means of examining inorganic substances should have been, ever since its first discovery in Sweden, treated in Britain, of all countries in Europe, with undeserved neglect, but this certainly seems the case, for, if we except the admirable and still unique pyrological method of detecting *boric acid* devised by TURNER, we find scarcely a single valuable suggestion in this mode of analysis originating with our countrymen, who appear to have ever practised it with but faint regard, and even in that modicum of attention, to have followed, as in a matter of little moment, the routine laid down for them by the Swedes and Germans; and it is evidently upon this lukewarmness of our scientific men in the beginning of this century, that Berzelius reflects when he says, "In the other parts of Europe only one, but he a most distinguished naturalist,* has investigated in detail the use of the blowpipe."

(33). One reason apparently, which has caused our scientific men to neglect this admirable mode of analysis, is the almost systematic degradation by which it seems to have been committed, as a science, to a place not only secondary to its just merits, but, as it were, to subserve the most rough, ordinary, and even barbarous purposes. Thus, a writer for whom I have the greatest personal regard, and who, had he persevered in his pyrological studies, would evidently have done much to redeem the science from the state into which it has strangely fallen in Britain, says, "The blowpipe is to be regarded as an auxiliary (!) to a knowledge of the physical characters of minerals, such as their hardness, color, lustre, and form of crystallization;"† and Berzelius says in the preface to his admirable book, "I hardly believe that anyone will succeed in arranging minerals according to their behaviour before the blowpipe." Certainly not; for we might just as well attempt to classify quadrupeds or birds by means of the chemical analysis of their flesh and bones, and indeed, it has evidently been too customary to make works on the "blowpipe" identical, or nearly so, with those on mineralogy, which seems to me a perfectly distinct subject.

(34). It is strange, nevertheless, when we remember this neglect, and consider that there has not been since, up to the present day, a single original British work on this subject, that the *very first* treatise upon it should have been published *in English*—in London—by a Swede, under the quaint but expressive title of 'A Mineralogical Pocket Laboratory.' VON ENGESTROM, the author of this treatise, first published in 1772,‡ presents us with the following description of blowpipe analysis, certainly the first ever given to the world in

* H. B. De Saussure.

† Translation of 'Scheerer on the Blowpipe,' by H. F. Blanford. Calcutta. 1855.

‡ The appreciation of Von Engestrom's treatise on the blowpipe in Europe, was shown by its immediate translation into his native language (Swedish) by Retzius in 1773.

any language, for Cronstedt evidently kept the means by which he had chiefly been enabled to draw up the first chemical system of mineralogy, as much as possible, a secret. "This way consists" (the italics are Von Engestrom's, and suggest a secret divulged) "*in a method of making experiments upon a piece of charcoal with the concentrated flame of a candle blown through a blowpipe*. The heat occasioned by this is very intense, and the mineral bodies may here be burnt, calcined, melted, or scorified, &c., as well as in any great works."

(35). Von Engestrom, then, may be considered as the pioneer of pyrological literature, for Cronstedt not only described few, or rather none, of the methods by which he arrived at the conclusions given in his 'Essay towards a System of Mineralogy,' but did not even acknowledge the authorship of that ingenious work; and, finally, it is impossible to recognize the reason given by Berzelius for this reticence, that "Cronstedt, who at first did not dare to allow himself to be known as the inventor of a system which has immortalized his name, was still less likely to publish a connected description (he published nothing whatever on the subject!) of his method of using the blowpipe;"* for Cronstedt himself gives (in the preface to his work) his reasons, thus: "I have thought proper to conceal my name to prevent any constraint on myself or others, and with a view to be at a greater liberty to amend the system whenever I shall be convinced there is a necessity for so doing, either by my own experience or by the observations of others." Cronstedt, in fact, appears to have been influenced by the ordinary feeling of anonymous writers; he wanted to see how his book would "take" before putting his name to it, for it must be remembered (though Berzelius seems to have been unaware of the fact) that Cronstedt was the acknowledged author of several scientific papers and lectures on similar subjects, already published by the Royal Academy of Sciences at Stockholm, so that it is too much to suppose his anonym to have been the result of *fear*, and, as Von Engestrom says, "he was soon discovered to be the learned nobleman, A. F. Cronstedt."

(36). Both Von Engestrom and Cronstedt,† however, refer to a "M. POTT, a chemist in Berlin," as having "proceeded farther than was customary before his time in the assaying of stones by fire, and as having afterwards published his acquired knowledge by the title of *Lithogognesia*." It seems strange, however, that neither Harkort, Plattner, nor Richter should have mentioned the claim of a German to have preceded Cronstedt in using the blowpipe mineralogically. It can be gathered, from the interesting account given by Cronstedt himself, that VON SWAB first used the blowpipe chemically at "*Westerwicken*, in the province of Dalarne in Sweden, in the year 1738," by

* 'Berzelius on the Blowpipe,' translated by Whitney, Boston.

† Cronstedt, 'Essay,' &c., p. ix., preface.

detecting with it, in a bluish-grey stone he had found at *Bowallen* in the neighbourhood, *the oxide of zinc*. Having thus satisfied himself of this fact, "he erected a work for distilling zinc *at large* from it."* Ten years after this, in 1748, Von Swab, in a course of similar experiments he had evidently been making upon sublimates of volatile metals, evolved by the blowpipe, discovered with it the true nature of a "mineral," brought some fifty years previously from Sahlberg in Sweden, and labelled till then in all mineralogical collections, "an arsenical pyrites." He thus found the so-called "mineral" to consist of *antimony* only, and it is remarkable as a proof of the extent of his new investigations, that he gives, as one reason for coming to this conclusion, the fact, "that, when brought into the form of a calx, it shot into crystals during the cooling." Cronstedt adds, in a note to this quotation from Von Swab's account communicated to the Royal Academy at Stockholm, "Since native antimony, or, as it is commonly called, regulus of antimony, was never before described, the possibility of its existence has been denied, and when this, here mentioned, was discovered (by Von Swab) somebody published some doubts of the truth of the whole affair, upon no better foundation than that *the specimens were very small for making experiments*, but that reason is not sufficient to refute experiments, *because men of experience are always able to make true experiments on small pieces of native metals*. We ought to be contented with conclusions drawn from experiments, until the fallaciousness of such experiments is demonstrated." I have italicized the part of this which shows conclusively that these experiments were made by Von Swab with the blowpipe, and published in the Transactions of the Royal Academy at Stockholm for 1748, to which Berzelius must have had access: why therefore that great chemist should have, in his history of the blowpipe, dismissed his account of Von Swab in the two lines—"he published nothing upon this subject, and it is not known to what extent he carried his researches"—I cannot understand.†

(37). But Von Swab apparently proceeded much farther in the chemical use of the blowpipe than the mere extraction of sublimates from certain minerals with it. In his article on *Borax* (which salt evidently sorely puzzled the philosophers of that time, for they thought it was an artificial preparation by "the Indians and Chinese"), Cronstedt says, "The mine-master, M. Swab, who has had an opportunity of making experiments upon this *Tincal*, has published them in the Acts of the Royal Academy of Sciences at Stockholm for 1756.

* Cronstedt, 'Essay towards a System of Mineralogy,' translated by Von Engestrom. 2nd edition. London. 1772, page 219.

† Since writing this, it has occurred to me that a reason might be found in the probability (from his name Von, sometimes written Van) of Swab having been a Dutchman?

(Cronstedt's own Essay was first published in 1758.) He says that he found in it, a martial earth and a fat substance, which, to smell and other circumstances, comes nearest to a mineral fat: as likewise, *that pure borax does not yield any hepar sulphuris when united with a phlogiston and a vitriolic acid*; from which he concludes that borax is prepared from its own particular mineral substance." *

Now the previous published researches of Pott, D'Henouville, and Margraff, had proved borax to contain a substance of "a particular alkaline nature;" and it is quite evident therefore, from the part of this account which I have italicized, that Von Swab here fused borax with a sulphate (probably Gypsum) or with sulphuric acid on charcoal (phlogiston), in the reasonable hope of getting a "liver of sulphur," or sulphide of sodium, which he undoubtedly *would* have got, had there been any *free* soda in the borax; so that his inference, that it had "its particular mineral substance" (Boric acid) was very just, sagacious, and perfectly correct. We see from this account therefore, not only that Von Swab must have been in the habit of using *soda* as a pyrochemical reagent, a discovery attributed by Berzelius to Cronstedt, but that he was quite aware of what is still one of the most important pyrological reactions of that flux. It would seem also, from the above-mentioned experiment, that Von Swab must have found—and the operator who thought of such a process must have observed—that, although he could not produce the "*hepar sulphuris*," the sulphate dissolved in the borax with effervescence, and that the bead was "pellucid" as before, or only tinged with the color of the base of the sulphate. Cronstedt, in his own description of borax, goes no farther than this, merely confirming Von Swab's experiment, and moreover, he speaks of borax "keeping itself in the form of a pearl on the charcoal when melted before the blowpipe," as a well-known fact. It would appear therefore, that it was Von Swab, and not Cronstedt, as Berzelius states, who first used Soda and Borax as pyrochemical reagents; but the credit of discovering these things is apparently given to the latter, because he was by birth a "learned nobleman,"—a Swede, and celebrated through Europe for his "chemical system of mineralogy," while Von Swab was a mere "mine-master," but one whose name ought not to be thus concealed from the eyes of posterity; until, therefore, we have some better evidence in published writings, of Cronstedt's investigations, it would not be doing justice to others to give him an historical place as an original pyrologist. He may surely, however, be fairly termed "the father of modern mineralogy."

Great indeed must have been the sagacity and genius of *that man*, who could discern in the use of a brass tube employed by the Egyptians apparently for

* Cronstedt, 'Essay,' &c., page 146, note.

soldering purposes, 1500 years before Christ,* and by goldsmiths and tin solderers all over the world, only mechanically, for many centuries, an instrument capable of attaining by one or two simple operations, half the results of a modern chemical laboratory, and a great many others, impracticable there, without it; and I can almost picture to myself this celebrated Mine-master, in that mid-winter night of 1738, at Dalarne, on the shores of the Baltic, *first*, amid the millions of human beings who had comparatively brutally used this instrument for so many ages, extracting with it "philosopher's wool" from *Calamine* or *Blenda*. He might then indeed, had he known them, have almost repeated to himself the magnificent lines of the poet:

"Then felt I like some watcher of the skies,
When a new planet swims into his ken;
Or like BALBOA, when, with eagle eyes,
He stared at the PACIFIC! and all his men
Looked on each other with a wild surmise:
Silent, on a peak in Darien."—KEATS.

As the science of pyrology, which is still more infantile in its development than any other, expands, so will the immortality of its progenitor, VON SWAB, be extended.†

(38). VON ENGESTROM'S treatise is full of sagacious, and even brilliant observation, which may well be studied even at the present day; he gives the following excellent general remarks: "Any gentleman who is a lover of this science will, by attending to the rules here laid down, be able in an easy manner to amuse himself in discovering the properties of those works of nature which the mineral kingdom furnishes us with. The husbandman may, by its help, find out what sorts of stones, earths, ores, &c., there are on his estate, and to what economical uses they may be employed.‡ The scientific mineralist may, by examining the properties and effects of the mineral bodies, discover the natural relation these bodies stand in to each other, and thereby furnish himself with materials for establishing a mineral system founded on such principles as

* *Vide* Rosellini 'I Monumenti dell' Egitto e della Nubia.' Parte seconda. Tom. ii., p. 292: Tavola iii. As quoted by Dr. Aquila Smith.

† The whole of the above partly-quoted passages in Cronstedt's work give occasion to a strong surmise, almost amounting to conviction in the mind of the reader, that Von Swab in reality applied the blowpipe mineralogically some six years at least before the date given in the text, and that it was chiefly through his knowledge of that application, communicated by Von Swab, that BRANDT, the chemist of Upsala, discovered cobalt in 1783, and the real nature of zinc, arsenic, and others of the "semi-metals" about that time. Nothing is more remarkable in the "System" of Cronstedt, than the systematic way in which he avoids speaking of the *blowpipe*, through the then almost unknown use of which he had been chiefly enabled to draw it up, and by means of which, as is evident from his own description, he discovered *nickel* in 1751.

‡ This is one of the few grammatical errors in these sentences, which are generally expressed in wonderfully good English, when we remember they were written by a Swede.

nature herself has laid down in them: and this in his own study, without being forced to have recourse to great laboratories, crucibles, furnaces, &c.; which is the reason why so few can have an opportunity of gratifying their desire of knowledge in this branch of natural history."

These reflections show a greater, and, at the same time, more just appreciation of the scope and neatness of pyrological analysis, than is evinced by any subsequent writer; not even excepting Bergman, Berzelius, or Plattner. The expressions also, are so grammatical and natural, as to make the remembrance that they were used by a foreigner, almost marvellous, unless, as indeed it is more pleasant to think, we may consider Von Engestrom, by reason of his long residence in this country, and perfect facility in the use of its language, a naturalized Englishman. He first noticed the fact of the prior oxidation of *Iron* and *Cobalt* in borax to that of *Nickel*, upon which Plattner's assay is founded.

(39). We now come to BERGMAN, an admirable epitome of whose pyrological labours is given in the 'Encyclopædia Britannica,' an. 1796, supposed to have been written by Wollaston. Bergman's high position as a chemist, mathematician, and friend of the great Linnæus, gives to his selection of this mode of analysis an unmistakable indication of its value and importance, which, I regret again to say, notwithstanding all these distinguished names, has still remained comparatively unheeded in Britain.

(40). It was evidently Bergman who discovered the method of oxidizing and reducing inorganic substances, by holding them in different parts of the "flame," first called by him "exterior" and "interior"—names they still retain,—for Von Engestrom says nothing about such effects; and Cronstedt had clearly missed the point when he thus referred to the fact: "Such colors as are communicated to glasses by *manganese*, are easily destroyed by the calx of arsenic or tin; they also vanish of themselves in the fire."* Bergman was also the first to use something besides charcoal as a support (he used a gold spoon of huge dimensions),† to observe the sublimate of arsenic and antimony on charcoal, and the color given by some substances to the "flame." Indeed, as regards the latter discovery, the beautiful cerulean blue given by chlorides to the green pyrochrome of copper, which is still one of the most effective and pretty methods of detecting chlorine, that reaction seems to have been attributed to Berzelius, without sufficient acknowledgment of Bergman's prior claim. Berzelius says (p. 82): "I made many researches to discover a test for chlorine in the dry way. A remark of Bergman, that chloride of copper tinges the flame green which is

* Cronstedt's 'Essay,' &c., Section cxiii.

† Berzelius gives (p. 31, Am. trans.) the credit of this device to Cronstedt, but there is not a trace of mention to be found in his 'Essay,' or, what is more conclusive, in the treatise of Von Engestrom, who gives two plates of drawings of the implements used by both.

not caused by any salt of copper in combination with a mineral acid, led me to make the following experiment," &c.*

(41). Now what Bergman said, as cited by Wollaston, is this: "Metallic salts communicate a certain color to the flame; blue vitriol and solution of copper in nitrous acid produce a greenness; but solution of copper in *spirit of salt* acts with much more efficacy: the green crystals of this first grow red by the contact of the external flame; afterwards they liquify and grow black, making the flame at first of a *deep blue*, which afterwards verges to a green." Again, subsequently, he says, regarding carbonate of copper, "with a superabundance of *marine acid*, it tinges the flame a *beautiful blue color*, but with a small quantity shows no appearance of the metal in that way;" which last remark shows conclusively that he attributed the blue color to the *chlorine*, and not to the *copper*. Berzelius describes, as if for the first time, in the list of reagents† the curious reaction of *gypsum* upon *fluor spar*, whereby they are made to detect each other; but a similar account is very distinctly given by Bergman.

(42). Bergman's treatise shows more careful observation, more systematic arrangement, and far more brilliant inductive talent than any writer who preceded, or most of those who have followed him; and to merely say that he "examined, with the help of the reagents described by Cronstedt (?), the greater part of the minerals known in his time, described their behaviour, and improved many of the instruments necessary for these researches,"‡ is giving him but faint and therefore unjust praise. As I have above shown, he made some of the most important discoveries which have ever been made in this science, not the least being that of carbonic acid gas; he reduced the *modus operandi* to a systematic process, in which the student is gradually led from the comparatively unsatisfactory examination of the "earthy salts," to the entrancing results of heating in this way ores containing the "metals proper," in which metallic copper, silver, and golden "globules" gladden his eyes,—a system which is still generally followed. Finally, I was surprised to find in reading this treatise that he had advanced a considerable length in the science of pyroelectrometallurgy, his experiments in which are most ingenious, and although unmentioned by Berzelius or Plattner, seem to me well worthy of repetition, with a view to quantitative determination. For instance, he says with regard to copper: "Even when the quantity of copper is so small as scarcely to tinge the flux, a visible pellicle is precipitated upon a piece of polished iron added to it (in borax) during strong fusion, and the globule in its turn takes the color of polished iron, and in this way the smallest portions of copper may be discovered." Now,

* 'Berzelius on the Blowpipe,' p. 82, American translation.

† Page 40, Am. trans.

‡ *Ibid.*, p. 5.

as the copper thus deposited must be pure, and the most trifling quantity recognizable in a balance, this method would surely form the groundwork of an easier and more elegant way of estimating that metal, than by the elaborate iron-cased charcoal furnace devised by Plattner.

(43). BLACK has left nothing behind him of his pyrological researches, but the ingenious blowpipe which bears his name. It is still (in England) the most commonly used of any, but that use seems merely on account of its cheapness, as it is made of tinned iron, which the better kinds cannot be, and is simply useless for the more delicate operations. Griffin says* that a German workman in Glasgow invented this blowpipe, not Dr. Black, but he gives no proof of this assertion.

(44). It seems hard for an Englishman to refrain from mentioning here the great discoverer of the most essential point in spectrum analysis, WOLLASTON, who, according to a recent speaker,† “saw the lines” (the method of producing which *he* had devised!), “but did not observe them,” which Fraunhofer, who mapped them, is stated to have done. Surely it might as justly be said that Mr. Keith Johnstone discovered America, because he has mapped it so much more carefully than Columbus could have done? As is well known, Wollaston was an ingenious and careful manipulator with the blowpipe, but of this he has unfortunately left us no record whatever, except a wonderfully clever and portable miniature blowpipe, taking up when closed in the waistcoat pocket no more room than an ordinary pencil-case; and that this is not a mere toy is certified by Berzelius: “I have often employed Wollaston’s blowpipe, especially in pharmaceutical examinations, or when inspecting cabinets of minerals; and I have succeeded by its aid in many cases in detecting errors, and assigning to incorrectly-named specimens their proper places.” Wollaston invented the use of platinum foil instead of a spoon, a great improvement in some cases; and he also, as is well known, suggested the plano-convex *lens*, chiefly for pyrological purposes.

(45). GAHN, the next authority in point of time, affords one of the rare instances of a great reputation derived almost entirely from contemporaneous account. Indeed, if it were not for the delightful description of him given by Berzelius, Gahn would be almost unknown as a pyrologist, except for his ingenious and rapid way of detecting copper in poor ores, and for the method of supporting the fluxes before the blowpipe on a loop of platinum wire, invented by him. This latter invention, however, at once shows him to have been a *facile princeps* in the art. It is, beyond all question, the most important inven-

* ‘Chemical Recreations,’ Part I., page 111.

† Sir W. Thomson, President of the British Association in Edinburgh in 1871.

tion in the art of pyrology, after that of using fluxes for chemical purposes, and in originality of conception, it far surpasses that. Borax, as we have seen,* must have been used, although accidentally, by Von Swab, as a *chemical* flux, while there was not much originality in stepping from the use of borax to that of the "*Sal fusibile microcosmicum*" (called microcosmic salt from a Greek name for Man, *Μικροκοσμός*, it having been at that time only prepared from human urine), of which Margraff had just then given a full description in the Memoirs of the Academy of Sciences at Berlin. But it is far otherwise with the beautiful invention of Gahn. Bergman's blocks of charcoal, and huge gold spoon, probably struck him as being but little adapted, and, indeed, almost fatal to the delicate reactions and changes of color which these glasses were capable of showing; but the originality and resources of the mind which could at once step from this fact to the thought of holding out the glass as an index of the most delicate reaction, to be seen *through* in every direction, upon a mere thread of thin wire, must indeed have been very great. The expedient is as simple as it is perfect: the formation of the *loop* or ring is an invention of itself, and it seems a fortunate coincidence that the value of platinum as a pyrimpregnable substance was, shortly before that time, discovered. The form of blowpipe devised also by Gahn is far superior to any other.

(46). Gahn first found phosphoric acid in bones, and he must have made this important discovery with his blowpipe; for Berzelius allows us to understand that he practised no other method of chemical analysis. Berzelius also gives us an interesting account of the way in which his old teacher "obtained with the blowpipe distinct particles of metallic copper from different sorts of paper after burning quarter of a sheet to ashes"; and how he "detected tin in oxide of tantalum, although this metal formed only one *per cent.* of the mass." † With regard to these two experiments, however, there seems, to the modern pyrological operator, nothing very wonderful in the first (although I suspect the white paper of 1873 will not be found to contain copper), for I have myself detected ‡ in only a square inch of filter paper taken from a chemical laboratory, silicate of lime, sesquioxide of iron, a quantity of potash (as might have been expected), a trace of soda, and some chemical water, as, indeed, any tyro can also do with an $\text{H}\ddot{\text{B}}$ glass. As to the second, Plattner seems to doubt the possibility of obtaining thus pure tin in *Tantalite*, unless the iron has been previously eliminated by the "wet way"; ". . . welcher zur Auflösung der tantalsauren Verbindung dient und die Reduction des Eisens verhindert, bekommt man auf Kohle in einem guten Reductionsfeuer etwas metallisches Zinn." § There can be no doubt, however,

* Paragraph (37).

† *Vide post*, Paragraph (226, a).

‡ 'Berzelius on the Blowpipe,' Am. trans., p. 5.

§ Plattner, 'Probirkunst,' &c., Vierte aufl. Leipsig. Page 299.

that Gahn richly deserves the prominent niche on which his celebrated pupil has placed him in the pyrological temple of fame. The ingenious idea, which has been so generally employed, of applying and heating *a solution of cobalt* with "earths," for the detection of some of them, was one of the original resources of Gahn's fertile mind, and the beautiful color thus formed with alumina, ought, therefore, properly speaking, to be called "Gahn's (not Thénard's) blue." Berzelius says,* "of all the substances he tried, cobalt was the only one which gave a useful result." In this case, it seems probable that he did not think of a solution of *manganese*, which exactly supplements that of cobalt.†

(47). To BERZELIUS himself must be accorded, on the whole, the first place among pyrologists. It is true that the little gem of a book which he has left us on the subject is now almost entirely superseded on the Continent, and even in England (where neither of them are much referred to) by the more detailed and scientific, but, in some respects, prolix and verbose work of Plattner. Such a result is only natural, for scientific writers, however eminent and original, must make up their minds to the certainty, if not the actual sight, of their discoveries set aside for improvements or new discoveries, in exact proportion with the progress of the science they had, in their time, loved and interpreted so well. Even Newton's fame has partly succumbed to this law of supersession, and, indeed, it could scarcely be expected that in science, as in literature, a SHAKESPEARE should arise, who could at once strike the key-note of perfection. Berzelius did not publish his pyrological researches in a collected form until 1821, but he must have—and, indeed, he tells us that he did—for a long time labour with his tutor Gahn, almost exclusively with the blowpipe. Cronstedt died about 1765; Von Engestrom was at least alive, as is evident from the preface to his translation by Da Costa, then librarian of the Royal Society, nearly ten years after: Bergman died in 1784, and Gahn between 1810 and 1821. In the very year Bergman died, Galvani made his celebrated discovery, but the account of it does not appear to have been published in England until 1800, when Sir Joseph Banks caused that which Galvani had sent him to be published in the 'Transactions of the Philosophical Society.' In 1803, Nicholson and Carlisle published their almost equally celebrated experiment of the electrolysis of water.

(48). Berzelius at this time was twenty-four years old, and we can easily imagine him, dazzled by such brilliant and important results, and burning to emulate the fame of the discoverers, to have deserted Gahn and the blowpipe for Volta and the electric pile. We find him, accordingly, in connection with Hisinger, decomposing by galvanic electricity an immense number of saline solutions in

* Page 41, note.

† Vide Paragraph (113, a).

1803, and although the operators were not so fortunate as Davy, in the thought of attempting the decomposition of a solid substance as *potassic hydrate* in this way, the experimenters at least succeeded in thus discovering the "oxides of *Cerium*." But although his labours in this direction were not rewarded by such splendid prizes as those reaped by Nicholson, Carlisle, and Davy, Berzelius attained, chiefly through his electrical researches on the composition of salts, an influence and reputation in theoretical chemistry, which, although shaken during his life by Dumas, Laurent, and others, have not died with him, nor will they, we may hope, ever die. The beautiful modern system of chemical notation is entirely due to Berzelius, and although some of the great hypotheses for which he invented, and to the explanation of which he applied it, have been much changed, the fundamental principles are still the same, and they undoubtedly owe more paternity to him than (as some assert) to Lavoisier. But with his fame as a chemist we have little to do here. It is more germane to our purpose of studying this history to note the fact that he should, in his mature years, have employed his immense influence with the scientific world, to press upon their consideration, and especially upon the attention of the English chemists, the less brilliant, but even more (chemically) solid results, obtainable by a persevering use of the blowpipe, in the investigation of all inorganic bodies. "*Revenons toujours à nos premiers amours*"; so we find Berzelius, at the age of forty-three, returning to his pyrological propensities, and satisfying them by the publication of a book in which he speaks repentantly, and almost bitterly, of the happy days he had passed with his old master Gahn, now dead. That book, 'On the Use of the Blowpipe in Chemistry and Mineralogy,' has even now almost outlived his far more pretentious works on chemistry, simply because, in the former scientific path he was, except afterwards by Plattner, quite unequalled, and almost unopposed. The chemical analyses of Berzelius, second to none in accuracy, are still often cited by mineralogists and others, but who now-a-days sees (at least in English) his work on chemistry, while fresh editions of Gmelin, H. Rose, Fresenius, and others, are constantly being translated?

(49). In the postponed work on the blowpipe, Berzelius seems to have taken a malevolent pleasure in taunting the philosophers of that time with the result of so utterly neglecting, for other pursuits, that of pyrology. "Even the mineralogists of the present day," says he, in the preface, "who believe that an examination of the physical characters of a mineral is sufficient to determine its nature, would in many cases be able to obtain accurate results by the aid of the blowpipe, if their in general deficient knowledge of chemistry did not prevent them from using it with advantage; whereas they now often find

themselves deceived by the application of their one-sided and short-sighted principles.”*

Again, he says,† rather disrespectfully, with regard to Harkort’s blowing apparatus, “Several other similar contrivances have been proposed by different persons, but I pass them by, since all these attempts prove that the inventors had no correct idea of the use of the blowpipe, and it may with propriety be said that they might as well have proposed to play upon a wind instrument with a pair of bellows.”

(50). Every part of this work bears a strong impression of the exact and methodical mind of its author. First, a lively, though not quite correct history of the blowpipe is given, which has the effect of exciting the interest of the general reader, and insensibly leading him to the more dry, but still interesting details of the supports, reagents, &c., still artfully combined with *historiettes* of how Gahn tried this, and Mitscherlich proposed that. He then seems to leave the student — no longer a mere reader now — to grapple with the chemical details; and even these do not become absolutely technical, until the learner is introduced to Part II.—“The behaviour of minerals before the blowpipe.” It thus happens that the first part of the book of Berzelius is more like a delightful historical novel than a technical work, and the reader soon finds that, although the method of analysis expounded is certainly the “dry” one, there is nothing figuratively dry about the book, except the humour with which the various anecdotes are told.

There is, however, an evident desire of Berzelius, in the fourth edition, where the “behaviour of minerals” was first published in 1843,‡ to push his chemical theories regarding salts into the blowpipe examination of minerals, and to make those fit the “constitution” of the latter; which attempt not merely disfigures this beautiful work, but seems to impart to the latter half of it an air almost of absurdity: who, for instance, would now recognize in his “*Hemihypantimonio-sulphurous-sulphuret of iron*,” the plain mineral *Berthierite*?

(51). Berzelius arranges minerals according to his favourite electro-positive-and-negative method, or, what might be termed, after Faraday, “the anocathodal arrangement.” As he himself states, it does not much matter what arrangement is followed, considering there is an alphabetical index to the book; but it seems, to a merely naturally scientific observer, that however the electro-chemical arrangement may fit a classification of *metals*, it is awkward and confusing in the extreme with regard to minerals, where an electro-positive radical, such as zinc, is chemically allied to a negative one, such as sulphur; I

* ‘Berzelius on the Blowpipe,’ Introd. p. vii., American translation.

† Page 13, note.

‡ Vide Preface to Am. trans. Boston. 1845.

was therefore curious to see where, in his classification, he would place *Sphalerite*, and found he had given the preference entirely to the electro-negative element, while *Molybdenite* and *Realgar* are placed under the curious heading, "Hypan-timonio-sulphurous Salts!" To Berzelius we are apparently indebted for the elegant and effective method of detecting small traces of sulphur or sulphuric acid in minerals by the brown or black stain of Argentic sulphide which they leave on bright silver foil when moistened with a drop of water, after having been reduced on charcoal with soda. He also first, as it seems, proposed the simple and now universally used way of isolating silica in compounds by the pyrological solution of the bases in microcosmic salt, but I have found that even phosphoric acid dissolves at least 6 per cent. of desiccated silica; microcosmic salt, therefore, containing soda, would probably dissolve more than that, and indeed Berzelius himself remarks, "If the assay contains only a trace of silica, this is generally entirely dissolved in the flux." Bergman declares "that silica dissolves in this flux in a similar manner (only more slowly) to the way it does in borax."* The detection and estimation of silica by the effervescing way in which it melts when fused with soda to a clear glass, is universally attributed to Berzelius, but we find the fact stated with considerable detail by Bergman. "In *sal sodæ*, silicious earth dissolves with remarkable effervescence, and, if the earth dissolved exceeds the weight of the flux, it yields a pellucid glass."

(52). Berzelius was the very Pope of Chemistry in the first part of this century, and some even of his Vaticanatic remarks show the danger of theorizing before we are certain of facts; for instance, at page 86 of his work on the 'Blowpipe,' with reference to Dr. Turner's test for boric acid, he says, "The theory is this: fluoboric acid is formed and disengaged, colouring the flame at the moment that it escapes." Now, assuming that, by this process, hydrofluoric acid might be "formed" from the fluor spar used, and that free boric acid existed in the essay, it certainly seems contradictory of those very chemical principles which Berzelius himself so assiduously taught, that two acids, leaving all the bases present, should chemically combine together to "form" anything: and further, if this great chemist had tested his conclusion practically, he, of all men, would have found that hydrofluoric acid orangizes and almost destroys the green pyrochrome of boric acid, and that potash (the principal base in Turner's test) considerably *increases* it. It would rather appear, therefore, that the "theory" depends on the liberation of potash, which, combining with the free boric acid, "colors the flame as it escapes," &c.; but the sulphuric acid present—ignored in the above quoted theory—must be allowed to share in the production of this phenomenon. The principal invention of Berzelius in this

* This statement, however, is certainly not correct.

art was the beautiful and portable pyrological lamp he devised; a description of which will be found farther on; and to him also, apparently, we owe the ingenious and elegant method, so universally practised nowadays, of examining solids in open and closed glass tubes, over a spirit-lamp flame. It may here be said of this indefatigable chemist, that he collected and set forth in condensed and vigorous language all that had been previously known of pyrological science; that he gave to experiments and results, which were in some measure undetermined, the benefit of scientific, exact, and rigorous explanation, and yet in such an easy, lively, and unpretending way, as to make it intelligible to the unlearned student.

(53). AIKIN and VON KOBELL.—If Arthur Aikin had only applied his original and hereditary* talents to the pyrognostic detection of *constituents*, instead of to mere mineral identification, he would have taken a recognized place as an English writer on the subject; as it is, his little 'Manual of Mineralogy' (the sale of which seems to have been stopped by the publication of Phillips's work) is evidently the model on which Von Kobell's 'Bestimmung der Mineralien' has been framed; the only difference, apparently, being, that the former places "metallic lustre," or "non-metallic lustre," as orders, under the classification "fusibility," or "infusibility;" while the latter divides minerals into two grand classes, "metallic," and "non-metallic, lustre;" and places "fusibility" or "infusibility," as orders, under those. There is, in fact, "not a pin to choose" between these arrangements; and, in my view of the case, both are equally vicious. I have before stated that Berzelius (though, and probably because, he tried it himself) thought it impossible to classify minerals according to their pyrognostic behaviour, so that they could be identified by that alone; but Von Kobell has succeeded in this feat; though, it must be confessed, by a singular, if ingenious, device. He places minerals, two and two, in a kind of comparative category of identification; the evident dissimilarity between most of which couplets I should have thought to have obviated all necessity of comparison. For instance, he places *Franklinite* and *Magnetite* together; assuming it to be difficult to distinguish between them; whereas it is far more difficult to show in what two points their reactions coincide; and in overcoming this difficulty, Von Kobell is obliged (in the tenth edition of his work, published in 1873) to assume that these minerals are equally magnetic! The same remarks apply to most of the other comparisons.

(54). With HARKORT commences (1827, when his work, 'Pröbirkunst mit dem Löthrohre,' was published in Freiberg) a new era in blowpipe manipulation. Every previous operator had used this instrument merely to detect the

* He was son of 'Evenings at Home' Aikin.

quality, not the *quantity*, sometimes of an ingredient, generally of a mineral. When this first German writer (excluding Pott) took up the subject, he seems to have had in view the remark of Bergman—"the only defect is, that the proportions cannot be determined with any precision, and therefore, when these experiments can be tried on a large scale, it is always to be preferred"—and to have determined to render the art as perfect as possible, by endeavouring to remedy this "only defect."

(55). Harkort naturally considered, from his view of the case, the metallic state of such oxides as could be reduced to that, and thus separated from other metals by the blowpipe, to be the best for quantitative pyrological estimation; and having determined this point, it was only a natural transition for his mind to select *gold* and *silver* as the metals easiest reduced and separated by this means. Cupellation had for centuries been practised; though, by the way, Von Engestrom points out quite another, and a very curious, way of separating the silver in lead ores (§ xxxix.), which will be found cited at length in its place in this work; and having once realized the idea, all Harkort had to do was to devise the means of performing the roasting, scorification, and cupellation of argentiferous ores in miniature. I have not had the advantage of seeing Harkort's work, or a translation of it in English or French; but, as Plattner says: "Die silberprobe vor dem Löthrohre, welche Harkort zuerst angegeben und in seinem, im Jahre 1827 in Freiberg erschienenen Hefte beschrieben hat, ist eine der wichtigsten quantitativen Proben, welche man mit Hülfe dieses Instrumentes fertigen kann,"* it may be presumed that the description which follows, of the silver assay, has not been materially altered from that first given by Harkort.

(56). Assuming, then, the account of the silver assay given in Plattner to be in all important particulars the same as that devised by Harkort, the first thing which strikes the reader is the marvellous minuteness and simplicity of the description. In these qualifications the German chemists generally seem to excel those of the rest of Europe, but their fault is prolixity, which is apt to appear wearisome after the concise and pithy descriptions of Berzelius. The greatest objection to Harkort's silver assay is, that a glance over the thirty closely printed pages of the description show it to require more time and skill than the "wet" method of obtaining a more correct result. For a detailed examination of it, the reader is referred to the second volume of this work on Pyrological Quantitative Analysis. The most ingenious invention of Harkort,

* "The blowpipe assay for silver first proposed by Harkort and described by him in a work that appeared in the year 1827, is one of the most important assays that can be made with this instrument."

one which shows him to have possessed an original as well as a painstaking and logical mind, is his "*Assay Scale*."

(57). This is a parallelopiped of polished ivory, 7 inches long; having engraved upon it, down the middle of its whole length, an immensely acute angle, which is crossed by transverse lines marked 1, 2, &c., to 50. These lines cross the sides of this acute angle, all the way to the base of the long triangle, which is finished by line 50. It is evident that the farther these cross-lines diverge from the acute angle, the more broad space they will traverse; and in these broad spaces the small silver or gold balls, produced by the blowpipe, are placed with a forceps under a lens, when of course they will be seen to fit the widening sides of the acute angle, according to their diameters, while the cube of the diameter is proportional to the weight of the ball. The scale is only intended to estimate balls too small to be weighed in an assay balance; the largest, or that fitting No. 50 line, having a diameter about half that of a very small pin's head. In the Harkort scales now made at Freiberg, the percentage of silver which such balls would show in 100 milligrammes of ore, is engraved opposite each line; No. 1 line showing a percentage of only 0.00002, and No. 50 line, 3.49. Harkort's scale will be further noticed in the volume on Quantitative Analysis. (See Fig. 44.)

(58). What has been said of the verbose descriptions of Harkort may in some small degree be observed with regard to the splendid pyrological work written by PLATTNER, the first edition of which, under the same title Harkort used, appeared in 1835, and the fourth edition exactly thirty years after; this last, prepared for publication by his pupil and friend Richter,* some years after Plattner's death. If completeness of detail, extraordinary minuteness of research, patient observation, honest and simple description, can combine to make a perfect book, this is surely one of the most perfect books that ever was written. Every known fact regarding blowpipe manipulation; a good deal of ordinary laboratory work (introduced where the former was thought to be inadequate); the locality, appearance, formulæ, and behaviour of almost every known mineral; laborious and extremely scientific quantitative assays of some ores, alloys, and furnace products; a glance at spectrum analysis; stoichiometrical analysis; coal analysis;—almost burst the boards which confine the 670 pages of this wonderful work. Yet, where too much is compressed, some-

* There is something very affecting in the following passage of Professor Richter's brief and formal preface to the fourth edition, italicized by me: "As far as possible, I have confined myself to the previous labours of my instructor, *whom I can never forget*." It was thus with Berzelius and Gahn; but those only who have to labour amid the usual petty cares and vexations of every-day life, *utterly alone* and unaided, can appreciate that luxury of science—the co-operation of a sympathetic teacher, pupil, or friend.

thing must go wrong; and we here find, for instance, *Feldspar* and *Agalmatolite*, placed under the mineralographic heading of "soda" and "potash;" while the enormous family of silicates is briefly exemplified by such minerals as *Gadolinite* and *Zircon*. The fact is that, from page 152 to 455, or 303 pages—i. e. nearly half of this work—is simply a kind of pyrological mineralogy, in which, for instances, many silicates are ranged under the heads of potash, soda, lime, &c.; and *Columbite*, *Tantalite*, &c., under that of iron. The arrangement differs in the following respect from that adopted by Berzelius, who gives first and alone the reactions of pure oxides and acids: in the second part, those of minerals; while Plattner places all together under the head of "examination for the oxide," 1st, a list of minerals in which the named oxide is found, with their chemical formulæ; 2nd, the behaviour of the pure oxide; and 3rd, the behaviour of the minerals, or most of the minerals given. The leading monograph of each work is therefore, in fact, a mineralogy with an extremely defective classification; but mineralogy is a subject which, as I have before stated,* seems to me a perfectly distinct one from that of pyrological analysis; nor can we suppose that, if the matter were to be determined by choice, the mineralogist would take into the field with him *Plattner* or *Berzelius*, in preference to *Des Cloizeaux*, *Miller*, or *Dana*.

(59). Immense labour and patient observation, with an absolute intensity of method, are more remarkable in Plattner's work than originality or deductive ability; but yet, with this defect, it is by far the most valuable because the most complete one on this subject extant; for *RICHTER* has kept it even with the progress of the science up to 1865, and although his modesty does not allow him to mention the fact, he has evidently imparted many original additions and improvements to the book. The few inventions of Plattner were almost entirely applicable to quantitative analysis; especially what he modestly calls "a charcoal-holder," but which is, in fact, a little furnace, for assaying copper and lead; and the amount of heat which must evidently be kept up in such a machine, gives one an idea of Plattner's vast power of blowing (for he used only the mouth blow-pipe) of which I have heard the accounts of eye-witnesses; but these gentlemen, as I am informed, added, "There is no doubt that Plattner did these things, but no one else could do them."

Plattner's quantitative assay of cobalt and nickel ores is founded almost entirely on the observation of Von Engestrom, that in a combination of Iron, Cobalt, and Nickel, with sulphur and arsenic, these metals are oxidized before the blowpipe in borax in the order above given, and tinge the flux accordingly; so that the oxides are successively "slagged off." Von Engestrom says,† "When

* Paragraph (33).

† Section I., p. 309, 'Pocket Laboratory.'

cobalt ore is mixed with a quantity of iron, this last metal ought first to be separated, since it scorifies sooner than the cobalt;" and again, regarding nickel,* "When this semi-metal is mixed with iron and cobalt, it is easily freed from these heterogeneous metals and reduced to a pure nickel regulus by means of scorification with borax, because both the iron and cobalt sooner scorify than the nickel." But Plattner very much amplified Von Engestrom's observation, and he found in addition to it that by careful fusion on charcoal an arsenical "button" was formed, having the "constant" composition $\text{Co}_4 \text{As} = 38.46 \text{ As}$, and 61.54 CoO , and, after that was "slagged off," a "tetrarsenide of nickel," $\text{Ni}_4 \text{As} = 39.27 \text{ As}$ and 60.73 Ni . The chief objection to this assay is that in many cases native arsenic has to be added in large quantity, in order to effect the formation of these "constant" arsenides, from which operation the room is so filled with unwholesome arsenical fumes that it is recommended to perform the operation "outside;" but a detailed notice of this, as of other existing quantitative pyrological assays, will be given in Vol. II. of this work. While we must acknowledge the absurdity of the conception spread by some interested or foolish people, that blowing through a pipe by the pressure of the inflated *cheeks* only, injures the *lungs*, I think there is some reason to believe the report that Plattner really injured his constitution by perpetual use of the blowpipe, and, as some add, the tobacco-pipe. He was universally beloved, apparently, and his funeral was attended by every member (teacher and pupil) of the famous Freiberg University, among the latter of whom was my teacher, the late Mr. Hustler, of Rosemerryn, in Cornwall, some of whose Freiberg assays are given in this work.†

(60). Continuing this description of the progress of pyrology, it will be necessary—for I have only the alternative of abruptly breaking it off—to refer to some of my own labours in the art; and although the mention of them in connection with those of the celebrated men of whom I have been writing will, as I fear and feel, be considered presumptuous, I shall not allow such feelings to stand in the way of the progress of this science which I love so much. For I feel assured, that if I can only assist in weaning scientific Englishmen‡ from the unaccountable prejudice they seem to have entertained against this art, and from a too exclusive cultivation of other sciences, the discoveries which have been made by means of electricity and spectroscopy will not surpass those which may be made by means of pyrology.

* Section li.

† Plattner has made the immense improvement to Gahn's blowpipe, of a *trumpet mouthpiece*, the advantages of which, strange to say, Berzelius (p. 9) does not perceive; and it also appears to be unappreciated in England. I can only say that it lessens the inconvenience of long blowing by at least *one-half*, and very much facilitates rapid blowing, as in vesiculation.

‡ i. e. Britons.

(61). The weak points of blowpipe analysis, as exhibited by the last edition of Plattner, in 1865, were undoubtedly the detection of, or rather the failure to detect, the two common alkalies and the alkaline earths. Soda, *per se*, was certainly detected with ease by its orange "flame;" but as nearly every substance when held in the "exterior flame" * affords the orange pyrochrome, it was just this fatal facility of detection which made it so difficult to detect soda in presence of the "earths," &c. But it was found (1869) that no *oxides*, natural or artificial, except those of the alkaline metals, dissolve pyrologically in *boric acid*. Silica, alumina, and the metallic sesqui- or acid-oxides generally, remain quite infusible and insoluble in it. Lime and the alkaline earths are *fusible*, and combine with a proportion of the boric acid to form *balls*, some clear, some opaque, inside of the bead; but these anhydrous borates do not dissolve in it. When we remark, therefore, the beautiful pure green pyrochrome of boric acid, and that this is at once tinged with orange by the smallest trace of soda, and altogether overpowered by a greater proportion, it is easy to see that this acid forms an excellent detective for this alkali, which in O.P. leaves other acids apparently to dissolve in and combine with the former and tinge its pyrochrome; while all other bases not alkaline remain undissolved. If, therefore, we place *two* platinum wires containing boric acid beads in *the same* forceps, and heat in one of them some powder of the mineral we suspect to contain soda, bending the wire with the pure boric acid bead over (or under) the other, so that the O.P. passes over them in the same line, the pattern bead next the lamp, we can compare with the greatest exactness and simultaneously, the pure green pyrochrome with the sodaline boric acid one tinged with orange, while potash, on the contrary, *heightens* the green pyrochrome. (See Fig. 63.)

(62). This forms also, as may be imagined, a good test for *boric acid* itself; for if we examine in this way a mineral containing that, as e.g. *Tourmaline*, we find, although that mineral contains soda, it will not *orange* the green pyrochrome, because the trifling amount of soda is more than counteracted by the boric acid of the mineral, part of which acid, therefore, is still being added in a free state; and although it may be thus thought that this method will not at least detect soda in minerals containing boric acid, this is not the case; for by *adding* soda † to the mineral until we get the yellow tinge, we find that we have to add *less* than we should have if it contained only pure boric acid. And the difference in the proportions added, therefore, shows approximately the amount of *soda* in the mineral. It must be confessed, however, that Turner's beautiful method of detecting boric acid in tourmaline is an easier because a more direct

* This will be hereafter termed "O.P.," for "*oxyhydrogen pyrocone*." Vide Paragraph (87).

† Fused sodic carbonate powdered is best for this purpose.

one than this; but it involves carrying about potassic bisulphate and fluor spar for this one reaction.*

(63). But when *potash* is combined with a mineral containing also soda, though it be in the proportion of 20:1, the pyrochrome of the latter will quite overpower that of the former, so that the above method does not enable us to detect even a large amount of potash in presence of a little soda. The following expedient, however, will be found to answer the purpose perfectly, and to enable us to detect a trace of potash mixed with soda in the proportion of 1:20. The mineral, pulverized as finely as possible, is treated with O.P. in a boric acid bead, by which means a sub-alkaline borate is produced from the soluble portion of it (59). The bead is then removed from the pyrocone,† and blown into while red hot, with a jet having a *very large* orifice (a Plattner's blowpipe having the platinum jet taken off, answers the purpose excellently) just as the glass-blowers do. It is thus blown out into a large and extremely thin bubble or vesicle, which, if the blast has been too strong, is shattered at the further end; but that does not in the least matter. This vesicle is then breathed on strongly in the open mouth, when, if there has been any potash in the mineral, it will be covered with a blue cloud, which, when held some distance over a *very* small spirit-lamp flame, is dissipated in a moment, and the vesicle is quite clear again. As an illustration I copy the following from my note-book: "7-11-73. *Potash in presence of soda*.—(1) Applied a trace of *Cryolite* to a boric acid bead in O.P.: green pyrochrome completely *yellowed*. (2) Vesiculated [1] and breathed on the vesicle; a dull tarnish, like breath on glass, not evanescent by spirit-lamp flame. (3) Added a fragment of *Apophyllite* to [2]; vesiculated, and breathed on the vesicle: a light-blue cloud, rapidly evanescent over a spirit-lamp flame, although not one quarter of the fragment was dissolved. (4) Added *powdered Apophyllite* to [3], vesiculated and breathed on the vesicle: a beautiful strong opaline cloud, evanescent over spirit lamp." The reason appears to be found in the different degrees of attraction the sub-sodic and potassic borates possess for the warm moisture of the breath (for it was found not to be due to *anhydrous* carbonic acid), but the chemical *rationale* of the phenomenon is not quite so apparent. The *amount* of potash in presence of soda may be pyrologically estimated by a process which will be found in quantitative analysis.‡

(64). The utter weakness of the blowpipe examination for lime and the alkaline earths in 1865 may be gathered from the careful pages of Richter,§ who says, "The following indications are to be observed: Tumefaction and

* For the cupric oxide test for boric acid, *vide* Paragraph (217).

† "Flame" is so called by me, *vide* Paragraph (77).

‡ Vol. II.

§ Plattner, p. 194. American translation, by Cornwall. New York. 1871.

bubbling during the test for fusibility often seen in calciferous silicates; . . . most of these dissolve easily in borax, while with phosphor salt, not only is the silica separated but the glass also generally becomes opalescent on cooling." Berzelius, on the contrary, says* of lime, "It is dissolved *in large quantity* by the salt of phosphorus to a clear glass, which on cooling *remains transparent*." But Plattner more completely confesses the inability of the blowpipe to detect the two most important of these earths at p. 185, "Kalkerde und Talkerde kann, man *nur mit Hinzuziehung des nassen Weges* ausschieden und jede dieser Erden für sich der weitem Prüfung vor dem Löthrohre unterwerfen."† Now, as it happens, there is no known process, not even spectrum analysis aided by hydrochloric acid,‡ which can separate and detect these with the delicacy and exactness of pyrology. Spectrum analysis requires, not to speak of its *expensive* appliances, a comparatively large quantity of the earth to be operated on; in the case of such as Didymia, Lanthana, and Erbium, a matter of some financial moment, while some very important earths, as Silica and Alumina, give no spectrum at all as ordinarily burned. For the pyrological method a piece the size of a pin's head is amply sufficient, and the earths in this can not only be separated but extracted and weighed.

(65). All we have to do is to first calcine the fragment strongly, but this though better, is not, for qualitative analysis, an absolute necessity; powder it and apply some of the powder to a clear hot bead of boric acid. *Lime, Magnesia, Strontia, Baryta, Didymia, Lanthana*, congeal, as it were, with the aid of a minute but evidently regulated proportion§ of the boric acid of the bead, to small, but perfectly round *balls*, which, floating unconnected and quite distinct in the clear bead or glass (which would itself be a sphere if not restrained by the platinum wire) have a most curious and beautiful appearance. It soon strikes the operator that those earths, such as lime and strontia, which can be rendered nearly anhydrous by violent heat alone, form, when applied in this state to the boric acid bead, clear or translucent balls, contained within the bead of H_2B , while such substances as cannot be so quickly dehydrated, as Magnesia, Calcic Silicate, Oxide of Cobalt, &c., form *opaque* white or black balls; and the fact seems to afford an explanation of the well known phenomenon of magnesia, saturated with cobalt solution, remaining pink under the heat of O.P., for, it being impossible thus to dehydrate it, the cobalt solution retains its pink (or hydrated) color. The light which this magnesian ball seems to throw

* Page 52.

† Plattner, 'Probirkunst,' &c. Leipzig. 1865.

‡ It will be afterwards shown—Paragraphs (91) (144)—how a very simple expedient enables the operator to dispense with hydrochloric, or any other acid.

§ With respect to *lime*, the proportion is $W - \left(\frac{W}{4.5}\right)$; where W = the weight of the ball.

on the constitution of fused boric "Anhydride," has been already adverted to,* showing it, in this view, to contain chemical water.

(66). The fact then appears to be, that every alkaline earth, and each of some metallic oxides, as, e. g. Copper, Cobalt, or Manganese, having a different capability of partial dehydration by violent heat, exchanges chemically when thus applied to the boric acid bead and strongly heated in it, the whole or a part of the chemical water it still retains, for an equivalent of boric acid, to form a nearly but not quite anhydrous (for the equivalent of boric acid seems to contain its own water), clear, in the first case, and a partly anhydrous opaque—in the second case—insoluble Borate Ball. An illustration of the great practical utility of these phenomena has been given above.† The "earths," therefore, are not only now the easiest subjects to determine pyrologically, but they may be detected in such substances as charcoal, paper, a fly, a grain of wheat, &c., in a few moments, and with absolute certainty; for the *nature* of the smallest speck is easily ascertained through a lens in the clear boric acid glass, the convexity of the side of which affords additional magnifying power, while silica is easily detected in connection with lime by the appearances mentioned under its head. It is a curious fact that boric acid, although so mild in its behaviour to oxides, attacks and decomposes some of the metals; which property suggested to Plattner or Harkort its use in separating *lead* from copper in alloys by decomposing the latter and oxidizing the lead. As silver is also rapidly oxidized in it under a strong O.P., I use it for the purpose of "parting" that metal from gold.

(67). Many experiments were made (1869) with the view of fluxing boric acid with some substance which should increase and not detract from its acid character as an alkali does, and of thus giving the pyrologist an equal advantage to that of the chemist in commencing to attack substances with a strong acid. Providentially, these did not wholly succeed, and it was in the course of these attempts, that the discovery of the curious internal Balls (formed by Cobalt oxide) was made. It was then only a step—but a step which apparently had never been taken before—to the use of *phosphoric acid* as a solvent, supported in Gahn's way, and this substance turned out to be, under O.P., the most powerful acid known, for it dissolves and oxidizes gold with considerable rapidity, and even platinum a little, when that metal is applied in very small and thin pieces of leaf, forming a bluish glass. On charcoal, having first evidently formed a combination with carbon, H^{P} partly attacks, and partly reduces platinum to a brittle, fusible ball. This ball, apparently composed of platinic carbo-phosphide, forms a far better *solder* for joining pieces of platinum than

* Paragraph (21).

† *Vide* Paragraph (46), and the vignette on the title-page.

gold (which is now used) does, for, independently of its white color, although it is easily fused with a mouth pyrogene between two pieces of platinum at a red heat, once they are joined, no amount of similar heat can again fuse the combination, which is not the case with gold solder.

The many new reactions obtainable with phosphoric acid must be looked for in this volume under the proper heads, but it may be here mentioned that with it Cobalt oxide gives a new and most magnificent color, and that most of the pure metals, as zinc for instance, afford several reactions before those of the chemically prepared oxides begin, so that we have in this fact additional and heretofore unsuspected clues to their nature.*

(68). The use of *Aluminum* as a support, in the shapes of a plate, a spoon, and also as a tray upon which to catch, without the least injury, accidentally falling red-hot beads of phosphoric or boric acid or of soda with their contents in solution, will be described under the head of *Matériel*, but it is not too much to say here, that with the two new reagents above described, it will be found to have almost revolutionized this science, and to render operations which formerly were most formidable, as the *effectual* roasting of arsenides, sulphides, &c., comparatively easy; while its immense superiority to charcoal in the important matters of cleanliness, portability, and expense,† is simply indescribable. *Sulphides* are instantaneously detected upon it by fusing them with a small fragment of soda, and saturating the hot mass with a drop or two of water, when an inky black, disgusting smelling precipitate of sodium sulphide is produced, and *sulphuric acid*, as contained, for instance, in Gypsum, by the same means, only the precipitate is brown and flocculent, and by noting that great *effervescence* takes place on adding the water, for a few moments, while sodic sulphate is being formed. If *reducing* effects are required on aluminum plate, the substance is ground into a paste with some powdered charcoal and placed upon it, or the former can be placed *per se* on a small square of charcoal, and that on the plate.

(69). Following, is a chronological list of novelties in pyrological analysis, brought into actual practice since 1865, the date of the last edition of Plattner's work: details will be found in the body of this work. The presumed novelties are italicized. (1) *Vesiculation* of borax with oxides dissolved in it, and the curious corresponding crystals which form on the surface of the vesicle laid on cotton in ordinarily moist atmosphere; 1867-8. (2) *Vesiculation* of *boric acid*, containing alkaline traces, and detection of *potash* in them by breathing on the vesicle; 1869. (3) *The violet color* given by cobalt oxide to *phosphoric acid*, and the means of thus quantitatively estimating alkalies which turn it *blue* in certain

* *Vide* Paragraph (29).

† An assistant in one of the largest, cheapest, and best chemical establishments in London asked me 3d. for a piece of Swedish charcoal not much bigger than my thumb.

proportion; 1869. (4) *Spherespheres*, or contained *balls*, formed by cobalt oxide in boric acid beads; 1869. (5) *Metallic looking films*, formed over beads of boric and phosphoric acid held in a good hydrocarbonous pyrocone (H.P.); 1869. (6) *Decoloration* of cobalt with *soda* by *arsenic acid*; 1869. Delicate reactions of *oxide of silver* in *phosphoric acid*, by which it can be detected in most galenas; 1869. (7) *Structure of pyrocones*; 1871. (8) Cobalt solution reaction given by *lime*; 1871. (9) Reactions of *chlorine* and *fluorine* in H.P.; 1871. (10) Curious reaction of *soda* in *pyrophosphate of lime*; 1871. (11) *Separation* of substances, especially of *metals* in *alloys* by utilizing their different attractions for *heat*; 1871. (12) The use of *aluminum plate* as a support; 1871. (13) *Quantitative assay* of Cu. S. by PbO in phosphoric acid; 1871. (14) *Separation* of silica, alumina, ceria, and the alkaline earths, including Didymia and Lauthana, by means of their behaviour in *Boric acid*; 1872.* (15) *Hexagonal atoms*; 1872. (16) Opalescence imparted by *chemical water* to boric acid, by merely *fusing* the latter on *platinum*; Feb. 1873. (17) Quantitative determination of this *chemical water* in clear fused boric acid, by means of a *magnesian borate ball*; March, 1873. (18) *Separation* of silica and alumina by *lime borate balls*; April, 1873. (19) *Separation* of Didymium and Lanthanum borates from ceric oxide; July, 1873. (20) Detection of F, Cl, and S, by means of CuO in a phosphoric acid bead; August, 1873. (21) Detection of *phosphoric acid* in tourmaline by *boric acid*; August, 1873. (22) Manufacture of *platinum solder*, by fusing small pieces of the leaf on charcoal in phosphoric acid, and the formation thus, of a *crystal of platinum*; † August, 1873. (23) New reactions obtained by a *Solution of Manganese* in sulphuric acid; September, 1873. (24) *Mangano-cobalt solution*, with the same view; September, 1873. (25) *Artificial zeolite* formed by heating a mixture of caustic potash and pure alumina, for the purpose of detecting alumina or lime, *plus* a caustic alkali; October, 1873. (26) *Pyrological Candles* with metallic collars; November, 1873. (27) *Benzoline pyrological lamp* for obtaining the benefit of gas as a combustible in travelling; November, 1873. (28) Decomposition (apparently) of the hydrocarbonous pyrocone by holding caustic *lime* on the wick, and applying the pyrocone jet *over* it; November, 1873. (29) Increased luminosity given to the flame of a common candle by touching the wick with red-hot platinum (&c.) wire; November, 1873. (30) Yellow and brown *oxides of thallium*, obtained on aluminum plate from the metal; November, 1873. (31) Detection of sulphuric acid, by the *effervescence* caused by adding a drop of water to a natural sulphate (as gypsum)

* Professor Stokes suggested the extraction of the balls formed thus by these earths with cold water. I afterwards used boiling water, which effects this result very rapidly. Plattner appears to have used water for the purpose of extracting precipitates in borax beads.

† This crystal was afterwards presented by me to the University Museum at Cambridge; a description of it by Professor Miller will be found in Paragraph (263, f).

which has been fused with *soda* on aluminum plate; December, 1873. (32) *Decrepitation* observed to be *peculiar to certain crystalline forms*; December, 1873. (33) Solution and separation of *Silica*, by boiling with boric or phosphoric acid dissolved in water; 1873. (34) Sublimation of gold, silver, and other metals by fusing them in O.P. with a minute proportion of lead on charcoal over aluminum; May, 1874. (35) The employment of a *Spectrum Lorgnette*, to remain fastened to the head of the operator, for the purpose of observing the spectra afforded by E. P., &c.; July, 1874. (36) The curious crystallization of *soda* combined with a small proportion of *lime*; August, 1874. (37) The determination of the mineral constituents of *animal* or *vegetal organisms* by burning the latter on a bead of Hb , 1874.

(70). Some reference has already been made to original experiments by later writers on the blowpipe, so similar to those of former operators, that, in absence of an acknowledgment of priority, we can only take them to be surprising coincidences; but, in closing this account, I must call attention to one more almost marvellous coincidence, in which, not the thoughts and acts merely, but the very words describing them, have suggested themselves to two or four writers, some writing ninety years after the other.

VON ENGESTROM, A.D. 1772.

"Whenever anything is to be tried, one must not begin immediately with the blowpipe: some preliminary experiments ought to go before, by which those in the fire may afterwards be directed.

"For instance, a stone is not always homogeneous, or of the same kind throughout, although it may appear to the eye to be so. The magnifying-glass is therefore necessary to discover the heterogeneous particles if there be any.

THE AUTHORS OF A SMALL ENGLISH WORK ON THE BLOWPIPE, A.D. 1862.

"When we are about to enter upon the examination of a mineral substance, we do not begin immediately with the blowpipe; a few very simple preliminary experiments are first to be made, by which the succeeding steps of the examination may be directed. As it is a matter of some importance to save trouble and, above all, time, we shall state the manner in which we have been in the habit of proceeding. Our first care should be to select a homogeneous particle, which will be a matter of no difficulty if the mineral be crystallized; and should it be amorphous, a magnifying-glass becomes necessary to discover any heterogeneous matter should it exist, for

minerals do not always consist of the same substance throughout, although they may appear so to the unassisted eye. Next we ascertain the degree of hardness by scratching it with a knife, and if it resists this, we resort to the file. We may then try if it be attracted by the magnet," &c. (p. 10).

"After this experiment follows that to try the hardness of the stone in question with the steel. Colored glasses resemble true gems, but as they are very soft in proportion to these, they are easily discovered by means of the file. The loadstone discovers the presence of iron," &c. (pp. 283, 284).

(71). I have already stated* that it seems to me a radically bad and aimless plan to attempt to obtain the reactions of a mineral, *as a mineral*; to treat it (in the words of Dr. Smith and Von Engestrom) as though it were a homogeneous, instead of being, as even the purest minerals are, an extremely heterogeneous particle. If mineralogists think such a mode of examination helps them to classify minerals, I would not presume, with my defective knowledge of that subject, to question their judgment; but I must not omit to warn the student of pyrology, that if he expects to find in this work a bad (or good) mineralogy, he will, I fear, be much disappointed. Minerals will undoubtedly form the chief subject of his operations, but he must operate on them with a rigorous determination to confine him- or her-self (for this elegant mode of analysis is suited to ladies, as well as to the rougher workman) to ascertaining what, and eventually how much, of each substance is contained in the *compound*. Having found these tolerably correctly, if he thinks he can thus arrange his minerals in a pretty, classical order, there can be no harm in his doing that, and I have even attempted, as will be found, a kind of pyrognostic classification in this work; but such a view is quite beyond its immediate purpose, which is strictly that of *analysis*. I therefore recommend him to abstain from touching minerals or even salts, until he has gone through a complete "course" of pure oxides, which, as he requires such small quantities, he can obtain at a comparatively moderate price. He should then obtain, if possible, minerals which have been quantitatively analyzed in the "wet way," and in expressing my fear that he will be unable to procure such, I may also express my surprise that, considering the present multiplicity of chemical laboratories, the mineral dealers do not sell such cabinets at, if necessary, slightly advanced rates.

* Paragraphs (33), (53).

The reader here, then, will find merely a description of *typical* minerals pyrologically examined by my methods, chiefly those belonging to a cabinet obtained by myself at Freiberg. I do not accept the responsibility of their selection as types, but I can at least claim to have carefully and, I trust, correctly examined most of them. With this end in view, the space of an indifferent mineralogy is occupied in this work by copious examples and illustrations of analyses, not only by myself and my methods, but by others and theirs, which I have always found the best way of learning a thing; and with this remark I now leave the student to *begin work*, as follows.

MATÉRIEL, AND HOW TO USE IT.

(72). (a) *For producing natural pyrocones*: (1) *Lamps*: coal-gas lamps; oil lamps. (2) Pyrological candles.

(b) *For producing artificial pyrocones. Pyrogenes*: (1) The mouth pyrogene; (2) the hand pyrogene; (3) the foot pyrogene.

(c) *For working with*, (alphabetically arranged):

Agate slabs; mortars. Aluminum plate and spoon. Alphabetical note-book. Anvils, open and closed.

Balance assay. Bottles, water, washing, and dropping; assay oxide; cobalt solution. Brushes, soft and hard. Breaking cushions. Bulbs, glass (see test tubes). Borers. Basins, boiling. Blotting pads; blotting paper for suckers.

Crushers (*vide* forceps). Cupellating moulds. Capsules, platinum, aluminum, brass, horn. Compass. Color box. Cobalt solution bottles.

Drawing pencils.

Eraser, ink. Envelopes, old. Emery cloth.

Forceps; (α) crushing; (β) cutting; (γ) pyrologist's; (δ) ringing; (ε) holding and picking; (ζ) platinum; (η) boiling; (θ) aluminum plate; (κ) lamp. Files.

Glass tubes; measure; funnels; slabs. Geometrical pens, old.

Hammers.

Iron sheets. Ivory spoons; scale.

Lens with reflecting collar.

Magnet. Mortars, charcoal.

Platinum wires, foil, spoons, spatula, crucible with lid. Pipette. Pyrological portfolio. Paper, white. Prism, blackened.

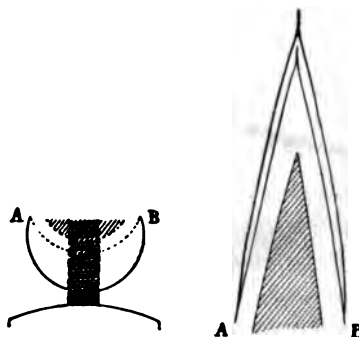
Spirit lamps. Saws, fine. Scissors. Sieves. Sponges, old. Suckers, blotting. Spectrum Lorgnette.

Test papers, blue and red. Test tubes.

FLAME.

(73). (a) *For producing natural pyrocones: (1) Lamps.*—We use lamps to produce flame; and what is flame? Simple as that question appears, it has puzzled philosophers of every time, and seems now as great a mystery as ever. Two hypotheses of flame structure are at present received by scientific men of all nations, with about equal favour. These may be briefly called (a) the incandescent-carbon hypothesis, and (b) the gas-pressure hypothesis. Taking the flame of a common candle as the best illustration, we observe that the shape of the flame is very nearly that of a cone of the common Scotch fir; that round the base of the cone a beautiful blue color prevails, which is terminated under perfect conditions, by an exactly level line, and that the wick in a good flame does not reach higher than this line; upon this line, A B, Fig. 1, begins the second or upper part of the cone, which consists of nearly white light, having in rainy or foggy weather an *orange* tinge; also beginning at this line, is a third conical envelope round the surface of the white or luminous cone, which at sea level has an orange color, but in high altitudes, a violet tint. But what is *inside* of the cone? The wick is inside of the blue part, and inside of the white or luminous part is a dark space, also of conical shape as seen from outside, which increases in height in a ratio with the flickering, or smokiness, or, in fact, with any irregularity in shape of the *outer* cone.*

FIG. 1.



Dissection of a Candle "Flame," divided into two parts by an imaginary line A B.

Now by the (a) hypothesis it is supposed that "in lighting a candle the combustible substance is decomposed, and combinations of carburetted hydrogen arise; but in the inner part of the white light cone, where there is a want of oxygen, solid particles of carbon are disengaged and attain a white heat, burning only as they escape out of the flame by the high temperature of the edge. It is therefore the incandescent solid particles of carbon which give to the flame its illuminating power."†

Hypothesis (b) contradicts the "free-carbon" suggestion of luminosity, and seems, to me, to entirely annihilate that, for it has been shown (by Frankland) that luminosity sufficient to read a newspaper two feet from the flame is

* *Vide* Paragraph (75).

† This description is condensed from the very clear one of Dr. Schellen, page 12.

obtained by burning pure hydrogen in oxygen, at a *pressure* of 10 atmospheres. It is a fact also, that flame luminosity is not due to free incandescent carbon, as is shown in the fact that if we suddenly put out a luminous flame with a vacuum extinguisher, we do not obtain a vestige of carbon, as we certainly ought to do if the (a) hypothesis be true, but only water. The black matter deposited by degrees on a cold plate held over a flame, is seemingly not carbon, but some chemical compound (as perhaps a hydrate?) of carbon (soot), having a strong smell, which carbon has not got. It also causes *opalescence* in boric acid under O.P., indicating the presence of chemical water,* which pure carbon never does. The experiment of gradual deposition upon a cold saucer looks more like a *condensing* process than any other. Frankland calls this soot "not solid carbon, but a conglomerate of the densest light-giving hydrocarbons."† It is a fact also, though opposed to the theory of statements found in works on the subject, that this soot can be obtained from the blue, or non-luminous part of a flame, and even from that of a spirit lamp, by holding in it certain substances, as, e.g. pure alumina, which have the effect of chemically decomposing it, and retaining the carbonic compound.

(74). Luminosity, then, is here assumed to be partly due to the *pressure* under which the various hydrocarbonous gases are burned in an atmosphere containing oxygen and steam, as air; but how is such pressure exerted or obtained on such a trifling scale of combustion as the burning of a candle? It may be in this way. The flame is kept in a *conical shape* by a cause which will be described in the explanation of artificial pyrocones,‡ so that the gaseous carburetted hydrogen combinations rise more rapidly than they can be burned, in a confined space (instead of being spread out) against the base of a cone of heated, but still, comparatively, immensely *heavy*, moist atmospheric air, which resists their progress before they can burn with the aid of its oxygen. *The pressure is thus exerted from below*, and this explanation seems confirmed by the fact (observed, I believe, by both Tyndall and Frankland) that, in high altitudes, where the atmospheric cone would of course be much lighter than that obtained at sea levels, and could therefore only afford a modified pressure, the blue part of the candle flame rises *much higher* than it does in the latter places. If we almost smother the wick of the candle with wax, so that the blue flame does not emit sufficient heat to create a draught, and thus lessens its pressure against the superincumbent air, its shape is that of a dome (Fig. 2), of which the apex bears a small luminous cone, A B.§ It will be observed that there is *no*

* Paragraph (15).

† Cited by Schellen.

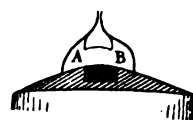
‡ Paragraph (84).

§ The two lines at the apex of the luminous cone are representations of what I observed; I don't know to what they are due.

hollow part in this figure, and that the relatively small luminous cone A B is *pressed into* the substance of the blue dome, and yet preserved distinct from that. On this hypothesis, the superior luminosity of a coal-gas flame would be simply due to the greater *pressure* brought to bear on the atmosphere at the jet by the ignited gas forced through a narrow jet, by means of a large reservoir, and as this force would overpower a single cone of heated air over the gas-pipe, it is necessary to reduce the orifice of the jet, and even to have two or more minute apertures, as in "fish-tail burners," &c.

(75). The blue "flame" is usually ascribed to "more perfect combustion from an additional supply of oxygen"; but I cannot understand how such a cause should produce such an effect, seeing that oxygen supplied in slight excess to any ignited body, solid or even gaseous,* causes it to glow with a *yellow* light, while this flame, containing the admixture of a considerable amount of oxygen, with its unignited gas, as in the Bunsen burner, has a deep blue color, just as it has when the oxygen is applied to it *after* ignition, as by means of the blow-pipe. Both of these phenomena appear to be due to the same cause—*absence of pressure*—although they are produced by totally different means. In the Bunsen burner, cold air is admitted to the pipe a few inches below, and rushing up mechanically, along with the gas, renders its density superior to that of the superposed heated atmospheric cone, which it consequently *raises*, and thus allows the carburetted hydrogen gases to be burned without pressure, or non-luminously. I cannot believe that the atmospheric oxygen, thus not combined, but moving with the gas, forms here a supporter of its combustion; for if we admit the same volume of air previously into the gas-pipe at a distance, say of 20 feet, so as to allow a thorough diffusion of the gases, we find combustion nearly ruined, and the flame, bad as it is, has moreover a strong *orange* tint. In the case of the "flame" obtained by the blowpipe, the ignited blue hydrocarbonous gases are also burned without pressure, and therefore non-luminously, by simply leading the flame formed by those gases in a horizontal direction, away from the wick, through the *mechanical* attraction that blue flame seems to have for the oxygen of the blast. This blast forces a way through the air, and thus removes the

FIG. 2.



Shape of a Candle Flame when the wick is supersaturated with melted wax.

* Bernays says, 'Chemistry,' p. 118: "A gas flame surrounded by pure oxygen gives very little light; but up to a certain point, an increase in the oxygen of the air, by accelerating combustion, increases the light of the flame." The statement in the text, however, refers to the color, not the light of the flame, while a saturation with oxygen is in no case understood, except that, of course, its *pressure* on the hydrocarbonous (or blue) part of the flame would be much less than that of moist atmospheric air. It will be afterwards proved that the blast from a pyrogene does not enter the blue "flame," and cannot, therefore, "supply it with additional oxygen."

horizontal pressure of the latter upon the blue flame following underneath it, while perpendicular pressure is also barred by the blast. If the blast is so weak as to allow the blue "flame" to apparently curl upwards at the apex, or end farthest from the lamp, perpendicular luminosity at once commences there, where, according to the "free-carbon" theorists, that carbon has been all "consumed" by "the perfect combustion caused by the additional oxygen" of the blast, and even then, not in the *body* of the artificial pyrocone, but as a delicate yellow line on its *upper surface*, exactly where the atmospheric *pressure* would be supposed to operate.

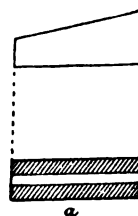
(76). It is by no means assumed here, however, that luminosity in a flame is due *solely* to pressure. That there is a combustible combination formed by the more dense, or upper part of the ignited hydrocarbonous gases, with some other gas possessing, under those conditions, perhaps, an equal density, seems evident: first, from the fact already mentioned,* that in a moist atmosphere the luminous flame has an *orange* tinge; and second, from the curious circumstance that, when the wick, supersaturated with wax or oil, and having therefore round it an *unpressed* blue dome of ignited blue hydrocarbonous gases, as shown in Fig. 2, is touched with a red-hot platinum wire, by which an instantaneous combination of these gases with those of the atmosphere may be presumed to be facilitated, the blue substructure bursts momentarily, at its upper surface, into luminosity; third, that if we take a lighted spirit lamp—the blue flame of which shows little or no luminosity, because its upward pressure is so slight that the light carburetted hydrogen gases of which it is composed are burned before they can be subjected to an adequate pressure—into a dense moist atmosphere, as a fog, its pyrocone instantly becomes semiluminous and deeply tinged with *orange*, evidently from increased atmospheric pressure. If we now drive, by means of a blowpipe, the *luminous* part of a candle flame through a like blue spirit-lamp pyrocone, we find the latter tinged with a *precisely similar* orange tint. The natural conclusion, therefore, is, that the luminous part of a candle flame contains, in considerable proportion, combustible gases, similar to some contained by moist atmospheric air.

(77). *Gas Lamps*.—Flames of a conical shape are called pyrocones; those formed naturally, as by a lighted candle in air, are called natural pyrocones; and those formed by other means, artificial pyrocones. The word "flame" is used to denote the substance of which pyrocones are composed, and that colored fire which many burning bodies emit is here called their "pyrochrome." The

* Paragraph (71). See also the article on the "Spectrum Lorgnette," in the Spectra of Spirit and Candle "Flames" obtained by which, the differentiation between their respective D lines seems to strongly confirm the above hypothesis.

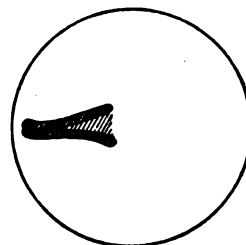
best natural pyrocone for producing an artificial *oxidizing* pyrocone, is formed by coal gas, having the common burner, with an angle of about 10° , and a strip of platinum bisecting its aperture longitudinally. The reason this platinum strip is placed there, is because in all natural pyrocones formed by the more dense carburetted hydrogen gases, as those produced by burning oil, fat, wax, and pure coal gas, there is a dark hollow nucleus,* in which there is no ignition, but gases which are stated, though I think on insufficient grounds, to be purely combustible; forming, as alleged, an assumed reservoir of gaseous fuel for the pyrocone. This is said to be "easily shown" by putting one end of a glass tube into this central part, and igniting the combustible gas which undoubtedly issues from the other. But if we insert the first-mentioned end of the tube into the *luminous* part of the pyrocone, instead of in the hollow nucleus, the gas issuing from the other end burns when ignited more strongly than before, and on blowing out the flame, not nearly so much smoke is emitted from the tube as in the first case. This smoke is, however, to some extent combustible, as may be seen by holding it under a bright gas flame, which is immediately tinged *orange* by it.† Now a slanting tube would undoubtedly create a draught, which might easily be supposed to suck in some ignited gas from the luminous part of the pyrocone, which would be extinguished by the narrow tube, but ignitable at the other end. Again, if we use a lamp or candle having *two* wicks, laid flat *together*, and spread these apart at one end (as in Fig. 4, which is the sectional view, natural size, of a pyrological candle), we distinctly *see* this smoke, rising in considerable volume into the central hollow part. The reason given for the possibility of equally combustible gas existing unignited in a place surrounded by flame, is the presumed exclusion from that place of all oxygen by the flame itself, but oxygen must surely be attracted in considerable quantity through the porous *wick* (of a candle for instance), heated by the flame, and when the *wax* is pared away horizontally, so as to make the wick disproportionately long, and thus admit *more* oxygen, the central nucleus, instead of being diminished, is, as has been stated,‡ increased in height. Besides, if we lay this central part *completely bare*, by blowing gently into it with the jet of a blowpipe held at

FIG. 3.



A Coal-gas Pyrological Burner.
a. Horizontal Section, showing a slip of Platinum foil.

FIG. 4.



Horizontal Section of a Cylindrical Pyrological Candle, showing the two wicks.
(Natural size.)

* Paragraph (73).

† This is not the case with tobacco smoke, which seems utterly incombustible.

‡ Paragraph (73).

least 2 inches from the flame, we get a curious insight into the *interior* structure of the pyrocone, and by a sectional view, an idea of the *thickness* of the luminous sides of the dark *nucleus*, which, in spite of the "additional oxygen" thus supplied, still remains perfect up to the part where the pyrocone is cut off by the blast.* It seems, therefore, more reasonable to suppose that this central space is filled with the *first products* of the combustion of the carburetted hydrogen gases, combined with a small amount of oxygen, and that the resulting smoke (whatever is its precise chemical nature) is slowly combustible by strong heat; is burned *per se* with an *orange* pyrochrome, but combines in some way or other with the blue burning gases under pressure, to produce luminosity. It has been seen† that we can actually reburn the luminous part of a candle flame, by directing it with a blowpipe against the wick of an ignited spirit lamp, when the flame of the latter becomes completely changed to a greenish orange, with an evident increase of density, and we can more simply decompose the luminous part of the flame of a candle with a rather long wick by directing *upon* the wick a strong stream of breath with a blowpipe, when the natural pyrocone is broken up into an irregularly shaped blue and orange colored flame, with little or no luminosity, the central nucleus being annihilated without extinguishing the candle, but only its luminosity, which indeed seems, in ordinary flames, dependent on this nucleus.

It will be seen from Fig. 2,‡ that the *blue* part of a candle "flame" is not hollow, but solid, which fact is evidently inconsistent with the theory that the hollow part of a luminous cone is filled with the same gases which feed it, for the existence of the blue part depends upon these very gases. Besides, these gases being as transparent as air is, they could not show a *dark* space when the natural pyrocone is viewed from *one side*, although a candle "flame" is certainly visible *through* the non-luminous part of another.

(78). Coal gas is almost useless for pyrological purposes, when it is required to hold the assay in the interior of its artificial blue hydrocarbonous pyrocone, because the latter is not quite solid, and because all coal gas contains sulphur in some shape, the presence of which may be proved by fusing pure soda on charcoal§ with gas by this part of the pyrocone, after which the soda will leave a black stain on silver foil with water, which it will not do when heated in an oxidating pyrocone.

(79). Of *oil lamps* by far the best, indeed the only one now used, is that of Berzelius (Fig. 5), charged with pure cocoa-nut oil (which, by the way, can be

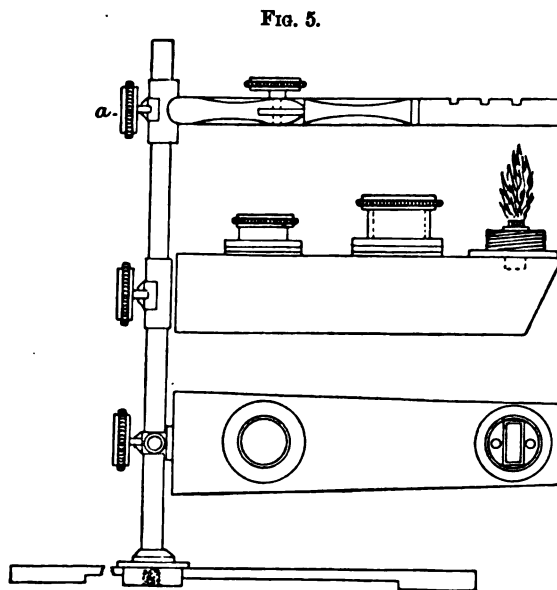
* By turning the wick of a lighted kerosene lamp without a chimney, suddenly down, we can obtain the upper half of its natural pyrocone, floating some inches above the wick in air, and thus showing the upper part of the inside of the nucleus very distinctly.

† Paragraph (74).

‡ Paragraph (74).

§ The test on aluminum is better still.

obtained cheaper at Battersea than in northern India!). This lamp affords most powerful pyrocones. At an elevation of 7000 feet, a blue hydrocarbonous pyrocone can be produced from it of such purity that sulphur, caustic potash, phosphoric and boric acids, can be immediately reduced by it to a metallic appearance on the surface, which results the operator may try in vain to effect at sea level. I use my lamp with two thin plaited wicks, laid close together, instead of one thick one, the advantage of which will be detailed in the description of artificial pyrocones.* The chief defect of Berzelius' lamp seems to me that the oil is apt to become too soon exhausted near the wick, which then becomes hard and smoky, affording thready luminous pyrocones, which spoil the assay. Oil, a supply of which it is absolutely necessary to take to



Berzelius' Blowpipe Lamp.
a. An Arm for supporting Capsules, &c.

wild places where minerals are most likely to be found, is a most inconvenient substance to carry, and if it escape, great injury to most articles is occasioned.

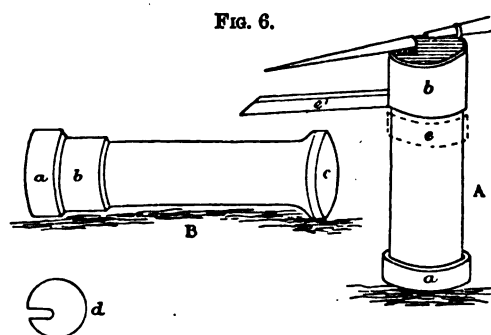
(80). *Candles*.—When we consider the portability, the cleanliness, and the purity of modern candles,† it is evident that if they fully answer the required purposes, they must form by far the best fuel for the travelling pyrologist. At present, however, they do not answer these purposes; the artificial pyrocones afforded by them are feeble and utterly inadequate; they gutter and drip; the wick soon becomes too long, smokes, and makes the artificial pyrocone thready and luminous: worse than even these defects, the wax‡ melts chiefly on one side only, from the heat radiated by the artificial pyrocone. If we attempt to remedy these defects by making candles of large diameter with an extra supply of wax, the latter melts with disproportionate rapidity round the base of the

* *Vide* also Paragraph (77).

† I am here speaking of those made for me by Messrs. Price and Co.

‡ By the term "wax," which is used for brevity, is to be understood the concrete fatty acids of which modern candles are composed.

wick, which soon renders the unmelted circumference comparatively higher, giving the surface the concave appearance of a saucer; and the small melted central portion being rapidly sucked up, the wick before long, rises "high and dry," affording a smoky yellow flame, about the worst possible one for pyrological purposes. But all these serious defects are remedied by the very simple expedient of placing a *metallic* (best made of zinc) *collar* or ring, about four fifths of an inch high and one tenth of an inch thick, fitting closely to the candle round that at the part where it is lighted. This ring is of course pressed down from the top as the *wick* is consumed, but as that is saturated by placing round it pieces or powder of wax (or drippings from the candle itself, which do not adhere on cooling to smooth tables or surfaces) to the extent necessary for pyrological operations, its consumption is *very* slow, and it only requires to be very slightly trimmed at the top now and then with a pair of scissors. There are *two* wicks (*vide* Fig. 4) in the pyrological candle now made for me by Messrs. Price and Co., and these are placed near the circumference, instead of in the centre, so as to obtain the whole use of the artificial pyrocone (Fig. 6).



A Cylindrical Pyrological Candle.

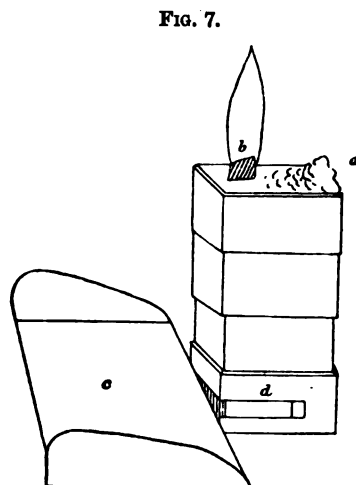
- A a. The bottom piece, of zinc.
- „ b. Top piece, or collar, „
- „ c. Middle piece, supporting tray e'.
- B a. The bottom piece, used as a cap to cover the wick in travelling.
- „ b. Top piece, of zinc.
- „ c. Dead head, of wax.
- d. Wax feeder.

The candle is in fact now a lamp, and affords, according to its size, an artificial pyrocone quite unmatched for power, purity, and certain important methods of analyzing, as the E.P.,* which cannot be effected by using a gas jet. A and B (Fig. 6) represent a pyrological candle (A) while in use, and (B) packed ready for travelling; (a) is a metallic cap, which protects the wick in the latter case, and serves as a stand or counterbalance to (b), over which it should be made to fit, in the former; when, as its diameter is necessarily greater than that of the candle, a

little wax should be melted in it, and the candle stuck in that. This wax adheres to the *candle*, not to the *cap*, when the latter is taken off cold, and gives to the bottom of the former a kind of "dead head" as at c. The collar or ring b fits not *too* tightly round the candle, and is gently pressed down by the two thumbs as the combustion of the candle requires; for which purpose it is never too hot. Before using, the flame is to be blown downwards with a mouth pyrogene all round the upper circumference of the candle, so as to well melt the

* Paragraph (90).

wax, the candle being turned round with the left hand for the purpose. Pieces of spare wax of the shape *d*, are made at my request by Messrs. Price, to fit into the top of the surface of the candle; and by this device, the wick seldom requires to be cut. A box of these is supplied with each packet of candles. The candles made for me by these gentlemen are so clean that they can be used, without injury, even on a polished mahogany table; for the wax cools so rapidly as it drops, to a cake (which can then be taken up with a table-knife, and replaced on the surface instead of *d*), that varnish, even, is not affected by it. In short, these candles surpass, in the important qualities of portability, cleanliness, and economy, all other descriptions of fuel. A smaller ring may be placed, as shown by the dotted lines *e*, for the purpose of burning the candle lower, and holding an aluminum or zinc plate tray* stuck between it and (*b*). Some scientific gentlemen have suggested to me improvements for this candle, in the shape of some elegant apparatus for pushing the candle from below, up through a metallic socket or tube as it burns; and it must be confessed that this machine (and drawing) devised by me, looks so simple as to be almost barbarous. But I fear these gentlemen have misapprehended the requirements in view, which any complication will tend to cause us to miss altogether. In the first place, the candle *could* not be pushed up through the socket, unless the latter was hot enough to melt the wax all the way down. In the second place, nothing can be easier than to press the ring (which never gets too hot for that purpose) down, as above explained. Thirdly, the weight and size for carriage would be increased. If the wax happens ever to run through the ring, the operator should blow out the candle; and when the former has congealed, put it back again. If the ring is not sufficiently hot to be pressed down when required, gently heat it with the pyrogene, blow out the candle, and press down the ring. Since the above was written, I have devised a more portable form of candle, of which I also give a figure (Fig. 7). In this apparatus the candle is a rectangular prism, having the wicks near one of the short sides. It thus packs quite easily into a portfolio, or even envelope, which the round candle will not. Messrs. Price and Co., with



Prismatic Pyrological Candle.

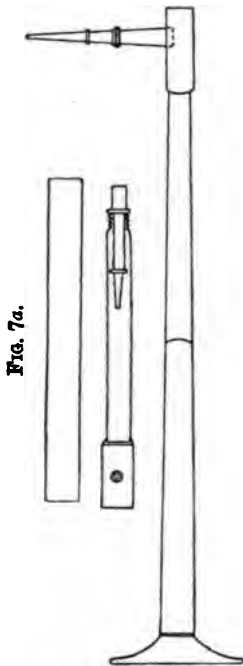
- a. A heap of spare wax.
- b. The two wicks.
- c. A zinc tray.
- d. The mode of fixing c.

* Paragraph (93).

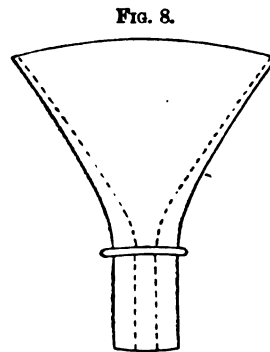
their usual obliging courtesy, made and sent me a couple of the new candles to try. The breadth (.75 inch), including the thickness of the zinc sides, was almost too little—I should think 1 inch over all would be about the thing—yet still, this candle answered admirably, but required a little more attention to prevent the lower wax from melting and running away through the joints. To prevent this, the wick must not be cut too low, as in that case the blue part of the natural pyrocone almost touches the sides, and heats them so much that the lower wax is melted, and runs down. To prevent this, some cold wax should always be kept in the front (*a*) as a reservoir, and the wick left as long as it is in the diagram (*b*). The tray (*c*) is of zinc polished or burnished inside with a smooth agate. Zinc conducts heat away from red-hot essays, whether metallic or dissolved in glasses, which may fall, leaving them cold and uncontaminated, almost as soon as aluminum does, and is of course much cheaper; it requires, however, to be oftener cleaned and polished; is heavier, and has a slight smell. The tray is fastened by two pins running into brass grooves soldered on the lowest joint, of which one only is shown at (*d*). The *perfect* candle-lamp and tray would be made throughout of aluminum; after all, not a very expensive matter.

(81). (*b*) *For producing artificial pyrocones.* (1) *The mouth pyrogene or common blowpipe.*—A description of the various crudely formed instruments for making artificial pyrocones, which have from time to time been designed since Von Swab applied the goldsmith's blowpipe mineralogically, would be out of place here. No one acquainted with the capabilities of Gahn's blowpipe, with Plattner's trumpet mouthpiece, would think of using the comparatively wretched affair still generally employed in English laboratories, and sold in our chemists' shops; and although such a high authority as Berzelius states, with reference to the immense improvement of the trumpet-shaped mouthpiece, "Plattner gives, as a reason for this arrangement, that the muscles of the cheeks are less likely to be fatigued by this method of blowing; this fatigue, however, is only occasioned by want of practice, and soon ceases to be troublesome when the operator has become more accustomed to blowing;" it must be remembered that Plattner was a far better authority in this case than Berzelius, having made this the employment of his whole life, and besides, made the most laborious quantitative assays of lead, copper, &c., with the mouth pyrogene, which the latter never attempted. There can be no doubt that the trumpet mouthpiece, pressed against the lips, *does* afford immense relief to the cheeks, the supervening flaccidity of the muscles of which, so far from "ceasing to be troublesome," increases to a painful extent by "practice." Another strong recommendation is, that in public laboratories, where the same instrument may

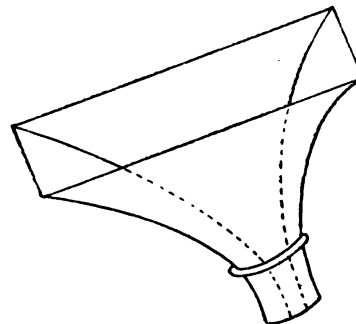
be used by different people, no part of it is put *inside* the mouth. A representation of this pyrogene is given in Fig. 7a, the box for holding water condensed from the breath being now merely a thickened continuation of the tube, which is made slightly wider, and divided by a screw in the middle into two parts, so that one may fit into the other after the manner of Wollaston's more portable, but not nearly so practical, blowpipe. Plattner tells us that the trumpet mouthpiece may be adapted to the shape of the mouth; and, taking the hint, I had a number made of wood in India (for 6d. each) of the shape and size of Fig. 8, which certainly suits me far better than the shape in Fig. 7a, though it is not so elegant. As these mouthpieces pack rather awkwardly, I am inclined to think



A Gahn's Mouth Pyrogene, with Plattner's Trumpet Mouthpiece, and Mitscherlich's arrangement for packing.



Section of the Wooden Trumpet Mouthpiece of a Mouth Pyrogene. (Natural size.)



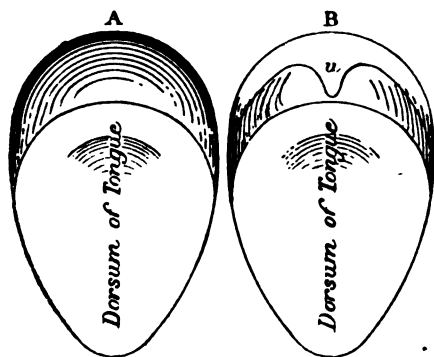
A Flat Pyrogene Trumpet Mouthpiece, which can be conveniently packed, and also fits the shape of the mouth. (Natural size.)

an improvement might yet be made, by employing a thin indiarubber flap between two wooden frames, which would fill out on being blown into, and when collapsed, could be more easily carried; but I have not tried this. As, however, the shape of the closed mouth, when the cheeks are inflated, is not a round orifice, but a slightly curved line, a mouthpiece the shape of Fig. 9 would

apparently be an improvement; and, if it answered at all, could evidently be packed in much less space than the round ones, and also lie much better on a table. There should be three jets of platinum: (α), with the ordinary orifice; (β), with a slit instead of a hole, for H.P.; and (γ), with a *very* large orifice for vesiculating.

A modern chemical writer, the second edition of whose work was published last year, says,* "It must be *remembered* that in using the blowpipe, the stream of air is not propelled from the lungs of the operator (where a great part of its oxygen would have been consumed), but simply from the mouth, by the action of the muscles of the cheek." It is evident from the above "explanation," that this chemist thinks it possible for a man to draw air through the nostrils *directly* into the mouth, without contaminating the air so drawn by contact with the lungs, and to store the pure fluid thus miraculously obtained, in his inflated cheeks for blowpipe purposes! Anyone who had once performed such an act would not be likely to easily forget it, but I would respectfully recommend to the attention of Drs. Gray, Carpenter, Professor Huxley, and other physiologists, this new "function of the respiratory organs" from a chemical point of view. There is no excuse for such a statement, even if it be urged that a knowledge of the *rationale* of using the blowpipe is not required by a chemical writer, for so long ago as 1815, Aiken gave the following correct description of the manner of

FIG. 10.



using this instrument; a description which, I regret to see, has been copied *totidem verbis*, without the faintest acknowledgment, by the distinguished writers of a lately published work.† "The first thing to be done, is to acquire the habit of breathing easily and without fatigue through the nostrils alone; then do the same while the mouth is filled and the cheeks inflated with air. . . . When this has been acquired, the blowpipe may be put into the mouth, and the confined air

expelled through the pipe by means of the muscles of the cheeks: as soon as the air is nearly exhausted, the expiration from the lungs, instead of being made through the nostrils, is to be forced into the cavity of the mouth; all subsequent supplies of air are to be introduced in the same manner as the first," &c.‡

* Page 105.

† 'Blowpipe Vade Mecum,' by the Rev. S. Haughton, M.A., F.R.S., and R. Scott, M.A. London. 1862. Pages 5 and 6.

‡ Aiken's 'Mineralogy.' Longman, &c. 1815. Pages 37, 38.

Aiken also recommends the operator to—"raise the tongue to the roof of the mouth, in order to obstruct the communication between the mouth and the throat," but it will be easily seen that this is an involuntary act which *must* be performed when the cheeks are inflated. The preceding diagram (Fig. 10) is a sketch (reduced to half-size) of the tongue and fauces: A, with the passage into the mouth closed; B, open; *u* is the uvula.

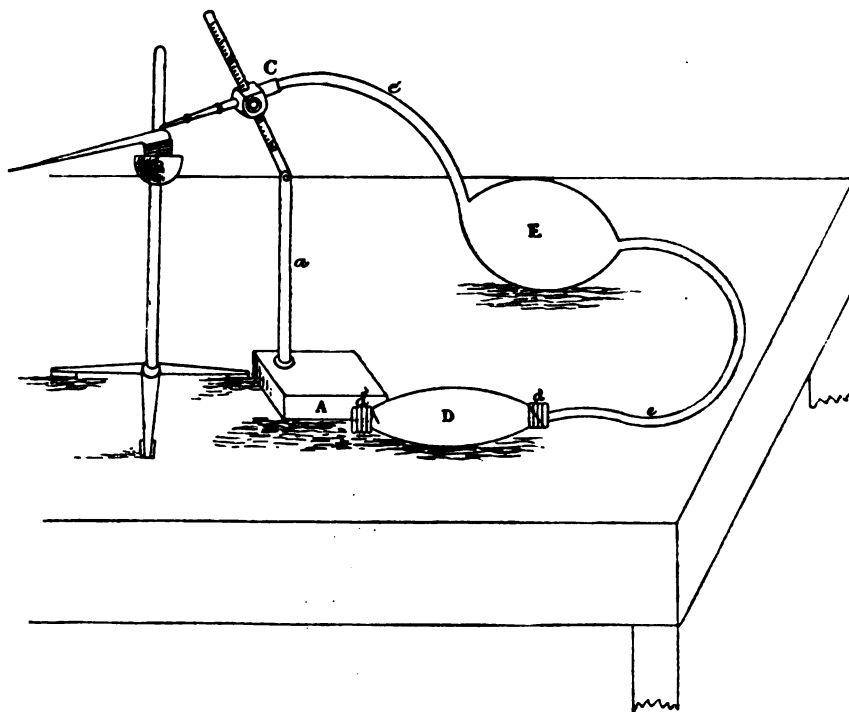
(82). So much instruction has been given in the art of blowing, by the various writers on the blowpipe, that I scarcely like to try my hand at it instead of copying some of their descriptions, but I find that none of these explain the way in which air is forced into the inflated cheeks while breathing through the nose, the mouth of course being almost shut. This is just the point the beginner cannot understand, for he can easily see (what is so carefully explained) that the air the operator drives out from his lips is not derived *directly* from an expiration of the lungs. He should first then try, with his mouth shut, to keep his cheeks inflated for some time, and breathe at the same time strongly through his nostrils. This he will find remarkably easy (unless he has got a cold, when the mouth pyrogene is useless), but he will not find it so easy to take the next step, which is to allow a very little of this air to escape through his nearly closed lips, so that he feels it on the back of his hand, and yet keep his cheeks inflated to the full extent, and go on breathing through his nostrils. If, however, he tries now to say *clown* repeatedly, without opening his lips any more, he will find, indeed, that he cannot say that word, but that each time he attempts to do so, he will only be able to pronounce the word *cock*; and each time he does that, a little fresh air is forced into his inflated cheeks, from the passage to his nose,* and far more too than is issuing from his nearly closed lips, while the breathing through the nostrils is not in the least impeded. This is the whole "secret" of the art, a secret which certainly seems almost laughably simple; and yet, only the other day, I was told of an able young mineralogist, who is deterred from pyrological experiments by the "difficulty of blowing." Having attained the power of continuously blowing on the back of his hand as above explained, the student should apply a pyrogene, as Fig. 7a, with a mouthpiece like Fig. 8 (which I am confident will further facilitate operations) to his mouth, and try to blow aside the small blue flame of a pyrological candle, saturated with wax.† He will be astonished at the effect such a small stream, fair or "blast," has upon it, and will probably succeed in blowing it out. He should then try to operate upon a luminous natural pyrocone of the same candle, and see how far he can project an artificial one from it. This achieved, he must, in future, be careful not to blow *too strongly*,

* i. e. by the arching of the soft palate and tonsils. Fig. 10.

† Paragraph (78).

which is the general fault of a beginner, and can now proceed to fuse a little phosphoric acid into a bead upon a ring of platinum wire,* and to effect and observe the phenomena of oxidation and reduction on a trace of copper oxide taken upon it.† With ordinary perseverance this much may be easily learned in a couple of days at most, but he must not be disheartened by little failures, which must have occurred, also, to such men as Gahn, Berzelius, and Plattner.

FIG. 11.



The Table Pyrogene.

- | | |
|---|---|
| A. The Iron Rest for the Pillar <i>a</i> . | D. The Bellows, worked by the right hand. |
| B. A Berzelius' Lamp. | E. The Wind Reservoir. |
| C. The Blowing Tube, clamped upon the Pillar <i>a</i> . | <i>ee</i> . The Blowing Tube, connecting D and E. |

(83). (2) *The Table, or Hand Pyrogene* (Fig. 11).—This instrument, said to be the invention of an American student, at Freiberg, is called there "Geblase." It is figured, but not correctly, the improved description being then apparently unknown, in the fourth edition of 'Plattner,' p. 8 (Fig. 6). If Berzelius could only have seen this simple, portable, and indeed, invaluable instrument in operation, or had tried it himself, he would, I feel certain, have excluded it from his sweeping condemnation of blowing machines.‡ In this figure, which represents

* *Vide* Paragraph (114, *a*).† Paragraph (140, viii. *i, f, d*).

‡ Paragraph (49).

a "Geblase" I bought at Freiberg in 1868, of Mr. Lingke, for a few thalers, A is an iron block or stand, 3 inches square by 1 thick, which is heavy enough to prevent the apparatus easily shifting on the table.* α is a jointed shaft or pillar upon which the jet pipe C screws, or clamps at any required elevation. This pillar screws into the block A near one side, which side is placed next the lamp. D is the bellows,† a stiff elliptical bladder of vulcanized indiarubber, fastened by wire strapping, on two short wooden cylinders d, d' , both of which are pierced by a small bore $\frac{1}{8}$ inch calibre and 1 inch long, closed by paste-board valves d, d' , opening from the outside. E is the air reservoir of thin caoutchouc, connected by the thicker elastic pipe e with the bellows D, and with the jet C by the thin elastic pipe e' . The bellows D is compressed by the right hand of the operator, gently or hard, slow or quick, according to the strength of blast required. The act of compression shuts valve d' , and opens valve d ; on being relaxed, the bellows resumes its elliptical form, and in doing so, of course draws air inwards, which has the effect of opening valve d' and shutting valve d ; thus the reservoir E is kept replenished, and it is necessary to equalize the blast from the jet. A similar apparatus is sold in London with a complicated "universal joint," &c., for other purposes, but at a comparatively enormous price: as above described it ought not to cost more than a few shillings. It is not suitable for giving a very gentle blast, or for vesiculation,‡ which must be effected with the mouth pyrocone. On the other hand, it possesses an advantage which has not (so far as I know) been before made available, of projecting a blast at a *certain angle*, high or low, according to the elevation of the jet C; which is of great service in changing the *nature* of the resulting pyrocone,§ and in order to utilize which, to its greatest extent, I have graduated the upper half of the shaft B of my pyrocone in tenths of an inch. (3) *The foot pyrocone* is precisely similar to that above described, only, having a longer elastic tube, the bellows is placed on the ground, and compressed by the foot instead of by the hand, which has the effect of spoiling all delicacy in regulating the blast, in proportion with the clumsiness of the action of the foot compared with that of the hand. Finally, as Berzelius says of the table blowpipe of Haas,|| "The operator has both hands at liberty, with which, however, he can do nothing."

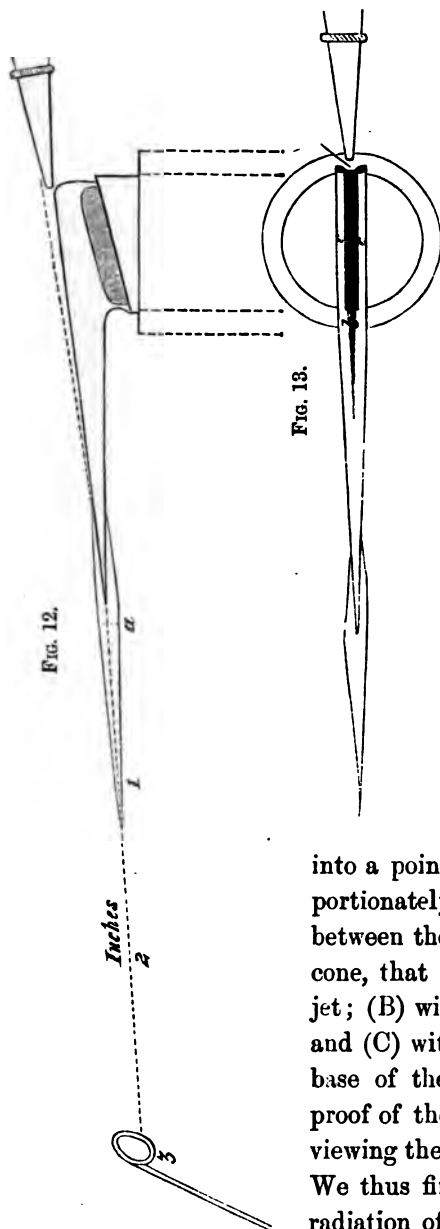
(84). *The artificial pyrocone* produced from the natural one by these instruments, has been before generally described¶ as to its *rationale*, but it may be added here that, on the application of a fine jet of air or breath to one side of the base

* I think this could be reduced in size and weight with advantage.

† My bellows having become injured in India, I procured another of English manufacture in London, which cost nearly as much as *the whole apparatus* in Freiberg!

‡ Paragraph (129, o). § Vide Paragraph (86), Fig. 16. || Page 12. ¶ Paragraph (75).

of the natural pyrocone, the gases in the centre are expelled; the luminous cone, unless the blast is too weak or applied too high, entirely vanishes, and what now



appears is a long *solid* tongue of blue light, terminating in a point of needle-like fineness with a violet-colored cone enveloping the apex, and extending with a more obtuse termination beyond it, to a distance commensurate with the strength of the blast. From the angle at which the eye of the operator usually sees the artificial pyrocone, and the difference between the diameter of the bore and of the outer circumference of the tube which forms the jet or nozzle of the pyrocone, the optical deception occurs, that, in the words of Berzelius, "a long narrow blue flame appears *directly before the jet*," and in those of Plattner, "the current of air passes *directly through the middle*." If, however, the lamp be held nearly level with the eye against a window, it will not be difficult to observe that the blast in reality passes *over* the blue pyrocone, drawing it underneath from the wick

into a point nearer to or farther from the latter proportionately (A) with the size of the angle enclosed between the line of blast and lower side of the pyrocone, that is, with the elevation or depression of the jet; (B) with the weakness or strength of the blast, and (C) with the quantity of ignited *blue* gas at the base of the natural pyrocone (Fig. 12). Another proof of the superposition of the blast is afforded by viewing the pyrocone from *above* as we blow (Fig. 13). We thus find not only that there is apparently no radiation of heat from the *upper* surface of the arti-

ficial pyrocone, which would of course be the case if the blast were "passing directly through its *middle*," but that we see the wick as a black band, having

evidently only a transparent medium like air between it and the eye. The most curious observation occurring to the operator in these two experiments is this. When held against the window as described, or in other words, when the artificial pyrocone is viewed by *transmitted* light, a slight ascending heat radiation is to be *seen* as a faint undulatory movement of the air: by careful watching, the blast, passing through this, is distinctly visible to good eyesight, as a *straight line* about the thickness of a fine needle. The shape of the blast on the other hand, as seen by reflected light, i. e. looking downwards with our back towards the window, as we blow over a lamp or candle, is clearly that of a Cone, the base of which is contracted or enlarged proportionately with the strength or weakness of the blast. If we blow into the flame of a spirit lamp from a very little distance, this phenomenon is still more striking, for the blast really is in the middle of *its* artificial pyrocone, so that we then see *two* synaxial cones, having their bases contracted and enlarged as above described; if we hold the jet a considerable distance from one side of the natural pyrocone, we see a wide cone formed in the flame, *but turned the other way*, i. e. with its apex *towards* the blast: the same appearance results if we insert the jet of the pyrocone half way into a lamp flame, as recommended by Plattner in blow-pipe cupellation (Fig. 14). The only explanation of the difference between the appearance of the *straight line* in one

view, and of the *cone* in the other, seems to me to be, that a blast confined between narrow limits as this is, forms a *Vortex* (invisible of course by transmitted light) in the air, by rushing through and displacing it, the sides of which (vortex), like those of a whirlpool in water, contract

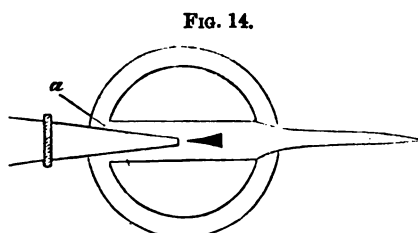


FIG. 14.

in direct proportion to the *rapidity* of the motion of its particles *round* (Fig. 17), or, as Sir John Herschel more scientifically expresses the fact, form "a vorticose motion, which, as a necessary consequence of the dynamical principle of 'the conservation of areas,' becomes swifter the nearer the indraughted air approaches the axis of the eddy."* If this hypothesis be correct, we have a very beautiful and simple reason for the *conical* or normal *shape* of flames (no explanation of which I remember to have seen even offered), and of the natural law which regulates the diameters of their bases. In the natural pyrocone, the "blast" is a draught upwards caused by heat and the movement of the gases themselves, which, apparently causing currents of air running in opposite directions, generate eddies, which assume a feeble vorticose motion; the resulting pyrocone, therefore,

* 'Meteorology,' Whirlwinds, &c., page 241.

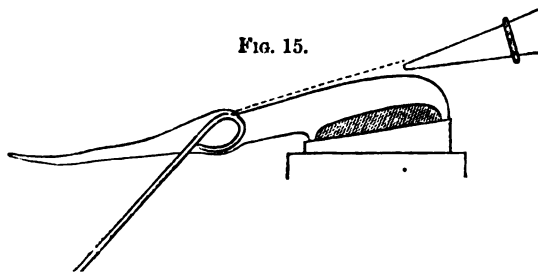
has a base with a large diameter. In the artificial pyrocone, the diameter of the base can be increased or diminished by blowing softly or with violence, the air-vortex enveloping both the blast and the pyrocone.

(85). The artificial pyrocone, therefore, may be briefly defined for practical purposes, as the hydrocarbonous base of the natural pyrocone, led away from it horizontally, as a *solid* cone, by means of a linear blast, and a surrounding vortex of air. I have at present no means of ascertaining the proportion which undoubtedly exists and ought to be determined, between the size of the natural pyrocone and the strength of the blast, for the formation of a good artificial pyrocone of any predetermined size; the operator on the small scale naturally settles this point each time by experiment, but this could not, of course, be done on a large scale.* *Luminosity* in an artificial pyrocone, although mentioned by writers on the blowpipe as necessary for what is called "a reducing flame," is simply a defect in it, which should, but cannot, always be avoided: it is in fact according to this hypothesis, the admission to it of vertical atmospheric pressure, and the experimenter soon finds that this luminous part of a flame does not possess nearly so much attraction for the blast as the blue part, and that the pyrocone formed of the latter, therefore, is invariably more regular and clearly defined. It is evident, however, that where the support is, as now used, a large piece of charcoal, the assay cannot be *enveloped* by the blue or hydrocarbonous part of the pyrocone, without bringing the former too near, and, indeed, almost touching the lamp, so that the only alternative is to cover it with the broken luminous *débris* at the apex of the cone, or, as some writers call it, to "spread the flames upon charcoal."

(86). *The Hydrocarbonous Pyrocons* (symbol, H.P., Fig. 15).—It will be easily understood from the above, that there is but one artificial pyrocone, and that the various terms met with, as "reducing flame," "outer flame," "oxidizing flame," &c., can only have reference to the *position* in which the assay is held in this pyrocone; that, in fact, it is the place of the object, and not the "flame," which is altered. These terms, therefore, are doubtless incorrect, but they have become so established by general use, that I shall only deviate from them so far as to apply them to the hypotheses here adopted. Keeping the fact, then, of the superincumbency of the blast, and the consequent solidity of the blue pyrocone underneath, in remembrance, we can readily understand that a roundish object placed in the latter about the centre of its longitudinal axis, having a diameter equal to or less than that of the pyrocone, will be wholly enveloped by the ignited gases of which the cone is composed, so that a bulb or jacket of them is formed round the front, i. e. that side towards the base of the pyrocone whence the current proceeds.

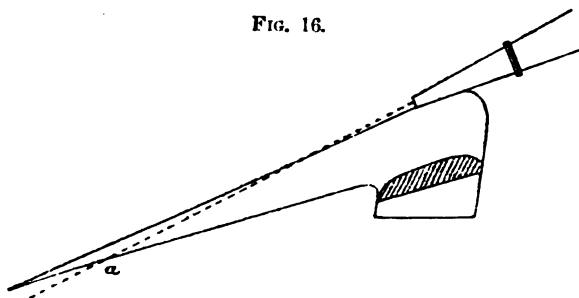
* Paragraph (82).

The object is thus apparently preserved from communication, not only with atmospheric oxygen, but with unignited gas of any kind. Such an envelopment is termed the *hydrocarbonous pyrocone*, which is made by blowing gently if chemical effects only, as e.g. the separation of chlorine and fluorine from lime, are required, but where greater heat is necessary, as in metallurgical or reducing operations, by a *high-angle blast* H.P. (Fig. 16), in which the blast traverses the natural pyrocone transversely, from a high angle, and thus produces, with coal gas, a blue and broad-based pyrocone of very great reducing power, for the angle a formed by the line of blast with the under side of the pyrocone is thus brought forcibly *within* the blue part. This is the hottest part of this pyrocone, as may be proved by introducing a platinum ring, which will glow whitest at that point.



A Hydrocarbonous Pyrocone.

(87). *The Oxyhydrogen Pyrocone* (symbol, O.P., Fig. 12 a).—When the jet of the pyrogene is placed almost level with that of the gas lamp or with the top of the wick of a candle, the angle a is just beyond the point of the blue, but about the centre of a pale violet cone,* evi-



A High-angle Blast crossing the pyroconical lines.

dently of the same nature as the outermost envelop of the natural pyrocone, and of much less density than the blue part. There does not appear to be much carbon, while there is clearly a large supply of oxygen in combination with hydrogen in this part of the cone; it is therefore termed *the oxyhydrogen pyrocone*. This position is termed in works on the blowpipe, "the oxidizing, or outer flame;" but that it does not always, or even often, exercise on the assay a complete effect of oxidation is proved by the precipitation of auric, platonic, cupric and many other metallic oxides dissolved in phosphoric acid, when held in this part of the pyrocone, which causes the bead to become dim, and often to change color; while that there is in reality no "outer flame"

* Paragraph (84).

is evident from the superposition of the blast. This point also is not necessarily, as has been supposed, the hottest part of the pyrocone, but only if the angle a is outside of the blue, when that angle, as before, is the hottest part (Fig. 12, a).

(a). The exact point of the pyrocone at which the carbon appears to have been completely burned may be surmised from the following experiment. Obtain by means of a P.P. from *Molybdenite* or pure molybdic acid supported on aluminum, a pretty copious yellowish-white sublimate on the plate.* Now approach the plate with the left hand, cautiously and squarely, that is, perpendicularly, against the pyrocone. It will be observed that when the surface of the sublimate is about 10 mm. or $\frac{1}{4}$ inch from the point of the blue, a spot of the beautiful indigo blue color, due to the formation of a lower oxide, called by the chemists *molybdic molybdate*, appears. I at first thought that this distance would have to be increased in proportion to the size—that is, the basic diameter—of the pyrocone; but this is not the case, the above-mentioned space being apparently invariable; and this is only natural when we reflect that both the pyrocone itself and the products of the combustion of its constituents are chemical compounds, in which each element precisely balances another. At exactly this point, therefore, the peroxidizing pyrocone commences, and the oxygen-hydrogen pyrocone ceases, to operate.

(88). *The Peroxidizing Pyrocone* (symbol, P.P.).—It has been before observed,† that a confined, continued blast appears to create round it in air, a *vortex*, the gyrative rapidity of which is least at the commencement, or greatest *direct* rapidity of the blast, and most when that begins to slacken. It seems contrary to expectation that the blast at its point of greatest violence and presumed direct rapidity, i. e. as it leaves the jet of the pyrogene, should excite the least rapidly gyrating part of the vortex; but this is not surprising, when we consider that the surrounding air has, at that point, only *commenced* to be drawn into the vortex: the more violently we blow, the *sooner* this commencement of gyration takes place, and consequently, the shorter is the diameter of the base of the vortex,‡ and the more contracted therefore the base of the pyrocone. But it is evident that the gyrative motion of the vortex will be much sooner exhausted than the direct motion of the blast, for two reasons: (α) because its initial velocity is less, and (β) because the former tends circularly to a point, while the latter is exerted in a straight line: a *fresh vortex* would therefore be created by the remainder of the blast, after the first one has concluded at a point a (Fig. 17) farther from or nearer to the base in proportion to the initial velocity of the gyrations. In this second vortex, however, the conditions of motion would be

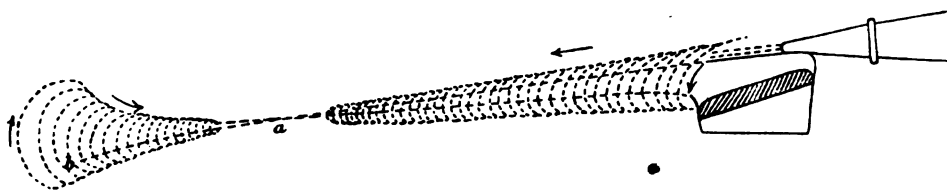
* Paragraph (235, b).

† Paragraph (84).

‡ Paragraph (84).

reversed,* the nucleotic blast being so rapidly exhausted as to be soon lost in the enveloping gyrations, which would themselves dilate proportionally to the loss of the motive of power of the blast, and contract most at the point where their motion round was most rapid, i. e. a little beyond the point *a*. The vertices of these two vortical cones, therefore, would point towards each other, and nearly meet at *a*, the point where it would appear that, the carbon of the blue pyrocone being (partly) consumed, its hydrogen for the first time combines with, in crossing,

FIG. 17.



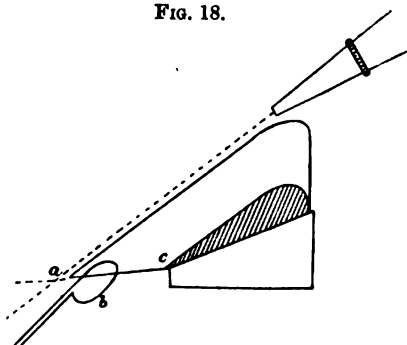
The Peroxidizing Pyrocone, showing the aerial vortex created by the Blast, which gives the Pyrocone its shape.

b. The inverted aerial vortex, which produces the oxidating effect.

the oxygen of the blast, forming there "the oxyhydrogen pyrocone" as a pale violet narrow ellipse (Figs. 12 and 13, *a*), which must still, however, contain a considerable quantity of carbon. But if the assay be held as at *b* (Fig. 17), the heat is still sufficient to cause molecular dislocation in most substances, while there can be little or no carbon here to exercise the slightest reducing tendency; but, on the other hand, an enormous supply of oxygen (*a*) from the direct action of the blast, and (*β*) from the gyrations of the second air cone. The name of "peroxidizing pyrocone" has therefore been applied to this point, but partly, also, because the symbol P.P. is thus made different from that of the oxyhydrogen pyrocone, O.P.

(89). *The Suboxidizing Pyrocone* (symbol, S.P., Fig. 18).—To obtain this pyrocone with a Berzelius lamp, first draw down the wick with the lamp forceps until its corner at *c* touches that of the lamp, leaving the other corner up the usual height; any irregularities on the surface must be cut away with the

FIG. 18.



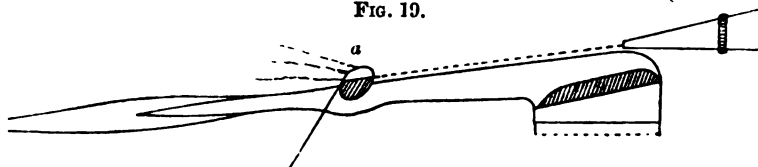
Extra High-angle Blast, showing how it may be made to exert an oxidating effect.

* About a year after this was written, I found in Sir John Herschel's 'Essay on Meteorology,' page 67: "The wind is most violent in the neighbourhood of the centre of the cyclone, but as the centre itself passes over any spot, a momentary calm is observed, the wind immediately recommencing in the reverse direction to what it had before (a necessary consequence of the vorticoose motion)."

scissors; this will cause the natural pyrocone itself to take a shape more triangular than conical, at the apex of which, the jet of the pyrocone is to be placed nearly parallel with the surface of the wick, which must be kept well saturated with oil: in a candle the wick must be cut to this angle. We thus obtain a blue pyrocone of abnormal basic diameter, the density of which is much too great to allow the angle a to be placed within it, as in Fig. 16, by any blast, however violent. The effect of this is, that although there is great heat at the point b where the assay is held, the oxygen of the blast cone is wholly excluded from that part, so that the assay, which appears ordinarily to oxidize in proportion to the extent to which it is heated in absence of carbon, provided it can obtain an extra amount of oxygen as that from the blast cone, is placed in a new position, in which the heat greatly exceeds the available oxygen, the consequence of which appears to be suboxidation. The effects of the process called "flaming," invented by Berzelius, may be produced in a flux like phosphoric acid, with more certainty by this pyrocone, which also has the curious power, apparently, of inducing crystallization in the bead when it contains some protoxides, as lime, in solution.

(90). It is sometimes, though not often, necessary to subject the assay to a modification of the full effect of the pyrocones above described. I have found in practice, that when I wish to subject my assay to considerable oxidating, but some reducing influence at a low red heat, as in bringing out the color of some of the chromatic oxides, the position a (Fig. 19) is best calculated for the purpose. The under half of the object is here evidently subjected to a reducing, and the upper half to an oxidizing influence, and it is also evident that the operator can at pleasure increase either effect by moving the object respectively

FIG. 19.



Pyrocone, showing the oxidating line of action of the Blast.

towards the vertex or base of the pyrocone, oxidation being of course the prevailing influence on the upper side from the presence there of the blast, which, by the way, seems to be the cause of the hot glass or bead spinning round inside the platinum ring, the blast acting on one side of the surface only.

(91). *The Ellychnine Pyrocone** (symbol, E.P.), by means of which a mag-

* From the Greek *Ελλυχιον*, the wick of a candle, because the assay is made, as it were, the wick, in order to produce this beautiful coloration, which can only be faithfully represented by a colored drawing.

nificent fire coloration is produced by some substances, as e. g. caustic *Lime*, from which this delicate characteristic could, in some measure, be obtained heretofore, with hydrochloric acid. It can only be perfectly effected with a pyrological candle or an oil lamp. The wick of the former is to be well saturated with wax, and the platinum jet (β) used, when a perfect blue pyrocone will be produced. The substance, or fragment, in a platinum hook, is first to be heated till it glows, the heated side approached on the under side of the pyrocone, and the wick gently touched with it, when the blue pyrocone will be splendidly tinged with the characteristic pyrochrome of the substance.* A similar but weaker effect is produced by approaching caustic calcic carbonate—a fragment of burnt egg-shell answers the purpose—*up* a gas pyrocone, i. e. from apex to base, when the red tinge is produced in proportion to its approach to the latter.

(92). *Matériel* (c) for working with. (Alphabetically arranged for the sake of convenience.)

AGATE SLABS and MORTARS.—Two rectangular slabs of agate 3×1.5 inches, and 1 inch thick, polished on one side, smooth on all, are preferable to the mortar and pestle usually sold with pyrological apparatus: (1), because they are cheaper; (2), because the polished side when scratched by grinding quartz, &c., can be repolished almost for nothing; and (3), because they are also indispensable for mixing up assay pastes, &c., which cannot be done properly in the hollow of a mortar: the latter, however, are sometimes useful for holding globular assays, which are apt to roll off a slab. If any pyrologist, who has used an agate mortar for some months in the course of assaying silicates or other hard minerals, will examine its surface through a lens, he will be perfectly horrified to observe the cavities and holes over which he has been grinding perhaps weighed powders. Still more serious consequences result from the retention, by these cavities, of metallic fragments. Plattner, therefore, recommends these holes to be *cleaned*, before use, with moistened bone ash.† Muspratt amusingly translates this caution as being in order “to *completely fill* all the small crevices with bone ashes,”‡ so that the operator in this case would have the pleasant addition of calcic phosphate to his assay! To use these slabs for crushing hard substances, a small fragment is to be placed on one of them, and broken with the (α) Forceps, in the manner described under that head,§ into very small fragments or coarse dust: if it is desired to lose none of this powder, a piece of clean white paper is placed on it, and the other agate slab pressed strongly over all; the resulting medium-dust being swept from the paper and edges of the lower slab into the centre of its surface; the other slab is now to be

* *vide* Paragraph (144).

† Page 45.

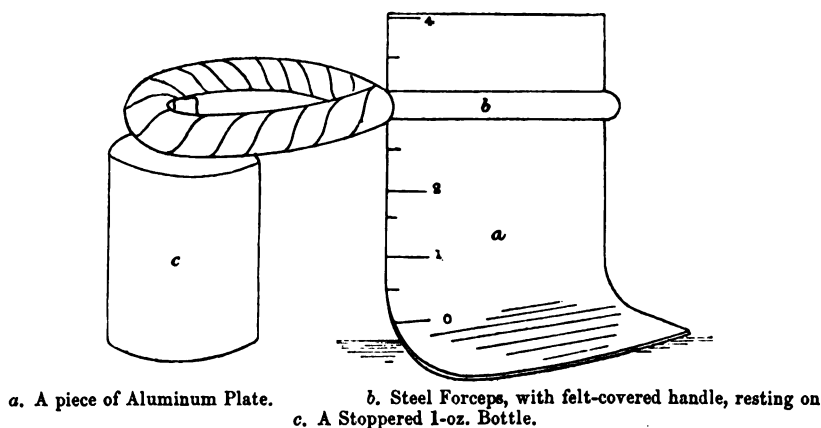
‡ Eng. trans., p. 23.

§ Paragraph (98).

pressed on the under one, bearing the powder, without the paper; and finally, the upper agate is to be rubbed circularly over the under one (if a paste is required, with the addition of a drop of water), until a dust is produced far finer than can be obtained by use of the mortar. These slabs are especially useful in examining infinitesimally small precipitates and residues from boiling water, which would be lost in a filter, in boric acid. These, and other uses will be described under the several heads.

(93). ALUMINUM PLATE and SPOON are quite indispensable: the first is used, (1), as a tray under the lamp or candle, with the edges slightly turned up, placed two or three inches below the pyrocone, beyond the utmost length of which it should extend (Fig. 6). After trying iron (as Berzelius recommends), agate, platinum, and other substances for this purpose, I found aluminum infinitely superior to all, from the same quality which renders it unmatched as a support, viz., its enormous power of heat conductivity. When a phosphoric or boric acid bead, especially the latter, is dropped red hot on aluminum, it is deprived so rapidly of heat that it solidifies before it has time to adhere or attach to the surface of the metal, and can consequently be instantaneously taken up, unadulterated and unaltered, upon the red-hot platinum ring. Sheet zinc, highly burnished, answers the purpose well, but not so well. The flange, or side of the tray on the opposite or inner side of the lamp or candle, should be blackened so as to form a contrasting background, on which the blue pyrocone is distinctly visible; which is not the case with the bluish-white zinc or alumi-

FIG. 20.



num. (2), Aluminum, as a support, should consist of a rectangular strip of plate or foil, *not less* than 4 × 2 inches, of the thickness of this line (—), made with the side of the foil I use; half an inch of the lower end of which

should be turned up on a table, at an angle of 80° ,* as a lip or rest for the substance, and a space of half an inch both above and below the angle, burnished bright with the handle of a small ivory paper-knife rubbed smartly over it with a drop of water, or better, of sweet oil. The upper end is to be held by forceps, made specially according to my design for this purpose (Fig. 20). I purchased, more than a year ago, such a piece of aluminum of Messrs. Johnson and Matthey for a shilling,† upon which I have fused arsenates, arsenides, sulphides, antimonides, thallium, gold and silver alloys, &c., and it is as good now as the day I got it, so that the economy of this support, even as compared with charcoal, will not be doubted. It should be heated gradually all over with the point of the pyrocone before use, as if that is applied strongly and suddenly to a corner of it cold, the plate, if too thin, might begin to droop there. Aluminum seems to possess the same immunity from pyrological injury which platinum does, for exactly opposite reasons. Platinum conducts heat so slowly and with such difficulty, that the *whole* of the piece of foil cannot be raised to the degree of heat necessary to ensure the fusion of any point of it where the greatest heat is applied; while, in the case of aluminum, the conduction of heat is so rapid through the whole mass, and from that to the pliers or holder (which should also be made of a good conducting metal, as iron), that, in like manner, communication to the *whole* (largish) fragment, of a degree of heat sufficient for the fusion of any one point, cannot be concentrated on that point; and thus it seems, that even the smallest scrap of aluminum, although easily fusible at first before the pyrocone on charcoal, cannot, as nearly all other metals can, be thus fused into a ball. As it is now made, considering its small specific gravity, very cheaply, and is not unlikely to be still more so, I would even recommend its trial, when of course proportionately thick, and in contact with iron underneath, as a floor for some reverberatory furnaces (not for ores of copper, which metal seems to alloy it; or of mercury, which slightly attacks it), especially for desulphurizing or de-arsenicizing purposes, as a pure pyroxidizing agency is evidently quite unlimited on its surface; while valuable metallurgical hints would doubtless suggest themselves, as, for instance, when *tin* is fused thereon, and suddenly cooled with water, it becomes as hard and tough as zinc, retaining its great malleability. It is convenient to have *two* of these plates; one being kept brightly burnished one inch and a half up the long side of the angle of 80° , which is graduated in quarter inches, or in French measurements, to show the height of ascension of sublimates. Fig. 20 shows one of these graduated plates, held in the forceps, resting, while

* The Fig. shows an angle of over 90° , but 80° is correct.

† I was surprised to find the retail price of aluminum, even in such small strips, to be 60 per cent. *less* at Messrs. Johnson and Matthey's than at Townson and Mercer's the chemists, not far off: such a piece as that mentioned in the text costing at the latter establishment 3s.

hot, on a one-ounce stoppered bottle. The burnishing is easily effected with the handle of an ivory paper-knife and a drop of oil, after which it is to be cleaned with distilled water, and rubbed with chamois leather. A surface of about 2.3 inches square should be thus polished brightly enough to act as a mirror. This plate should be kept for obtaining sublimates only, and the assays should generally rest on a charcoal mortar; but even that will sometimes leave a black stain from the sulphur contained in it. Phosphates, with a metallic base, as e.g. *Libethinite*, seem to stain aluminum most, and sometimes even to corrode it.

(a). The amount of heat communicable by O.P. to an assay treated on a charcoal mortar, supported on aluminum plate, is evidently far greater than that obtainable by treating similarly an assay in the ordinary way, on a prism of charcoal alone; and this effect I ascribe partly to the reverberation of heat from the upright polished aluminum plate at its back, or rear, upon the assay and charcoal mortar; partly to the *isolation* of the latter on the aluminum, by which the greater portion of the heat bestowed is concentrated on its upper surface; the under surface, in contact with the aluminum, remaining comparatively cool, in consequence of the rapid conduction of heat by the latter. There is, in fact, a lower layer of perpetually cool charcoal, so that the upper layer remains proportionally hotter. At any rate, the lowest part of a charcoal mortar thus supported can scarcely be burned at all.

I made an aluminum *spoon*, which answers all the purposes of such, out of a piece of the "wire," 6 inches long and about one-tenth of an inch diameter (which I bought from Messrs. Johnson and Matthey, also for a shilling), by first hammering out the ends and then punching shallow cavities in them, as above described. It is more handy for some purposes than the plate, and answers especially well for heating fragments of minerals for the application of cobalt or manganese (sulphate) solution, which, by the way, coats the aluminum, on reheating, with a beautiful silver-white plating. The spoon must of course be held with wadding, and be heated gradually.

(94). ALPHABETICAL NOTE-BOOKS are best made of loose leaves, having the initial letter legibly marked or printed above, so that any number of pages may be added to any letter. If I had only thought of adopting this method of making notes sooner, I should have saved much valuable time, for I have great difficulty now in putting my hand on particulars of what I have written for the last five years. The student should never work without making notes, as, however crude these may be at first, they will generally contain hints, and at least show him afterwards his defects of expression and mistakes in operation.

(95). ANVILS.—The open anvil is a parallelopiped of polished steel, generally about 2 inches square by $\frac{1}{2}$ inch thick, for flattening metallic balls on.

It is apt to get rusty; to prevent which, and harden the surface, I plated mine with phosphoric acid and repolished it* in 1869, since when its surface has remained smooth and bright. The closed anvil, invented by Abich, affords an ingenious method of crushing a crystal or other assay without material loss. Fig. 21 represents the shape sold at Freiberg, in which *a* may be called the piston, *b* the cylinder, and *c* the bed; all of polished steel; *a* should fit air-tight into *b*, so that drawing it out makes a noise like that of a popgun, and *b* should fit as closely in *c*. To use it, *a* is drawn out, the crystal thrown into *b*, and *a* being replaced, is tapped with a light hammer on its head, and soon shows, by sinking, if the crystal is crushed, when *a* and *b* are to be carefully taken out of *c*, together, and the adhering dust brushed off their bottoms into *c*, where the

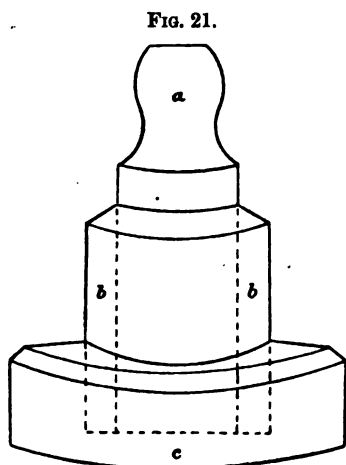


FIG. 21.
An Abich's Steel Mortar, for quantitative crushing of small crystals of minerals.

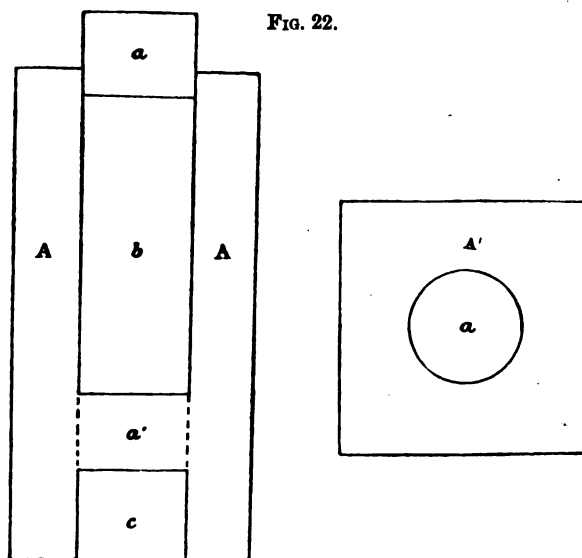


FIG. 22.

A modification of Abich's Steel Mortar, enabling it to be conveniently packed, and used also as an Anvil.

A. A. Vertical Section. A' Horizontal Section.

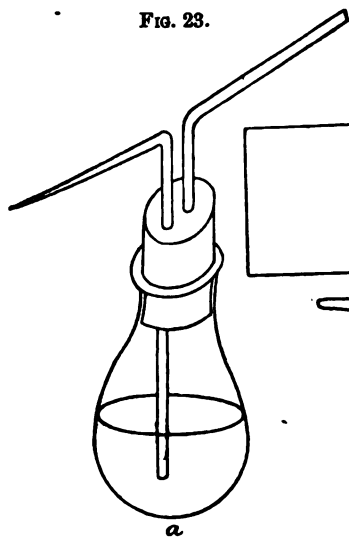
greater part of the powder is already found with a fine hair pencil. As Abich's anvil is very inconvenient to carry, the cylinder and bed requiring to be packed separately; as, moreover, the fine powder formed adheres so closely to the inside corners of the bed *c* (Fig. 21), that the last particles sometimes require to be *scraped* out, so that there is generally a loss of 1 per cent., I have devised the following modification. (Fig. 22.) The anvil *A* is a rectangular prism of polished steel, 2·5 inches long, the section of which forms a square of 1·3 inch. This is correctly bored longitudinally through the centre by a circle of ·7 inch

* Vide Paragraph (250²⁶⁶_g).

diameter. Into this bore exactly fits a piston, which is divided into three parts, *a*, *b*, *c*. Of these parts, *c* is the bed, and the anvil, when used, must be placed upright on that end, upon a smooth solid surface; *a* and *b* are taken out, and the fragment to be crushed placed in the space *a'*, occupied by the piece *a* when the anvil is not in use; but now *a*, being placed over *b*, receives the blows of the hammer, and of course, when it sinks to nearly level with the top of the anvil, the fragment must be crushed. To obtain the powder, *A* is placed on its side, and *a b c* pushed through on a sheet of white paper; *A*, of course, also answers for an *open* anvil on its outside.

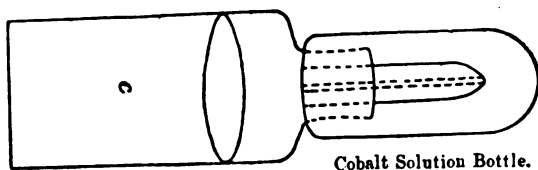
(96). BOTTLES (1) of the shape *a* (Fig. 23) and *b* (Fig. 24) are exceedingly useful though not absolutely necessary; *a* chiefly for covering beads, &c., with a certain amount of distilled water for boiling; and *b* for obtaining single drops

FIG. 23.



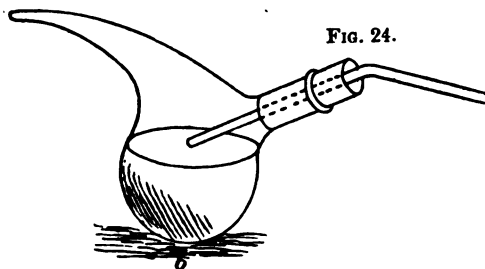
A Washing Bottle.

FIG. 25.



Cobalt Solution Bottle.

FIG. 24.



A Dropping Bottle.

of distilled water. *a* is called a "washing bottle" in the laboratory, but cannot be so used in these operations, as the quantity of precipitate is often too fine and small, and would be washed away altogether: it is, therefore, taken suspended in its drop of water on the agate slab,* while filters are not employed at all, as they are too coarse for this method, and, if burned with the assay, as is customary in some chemical operations, the silicates contained in the paper ash would utterly adulterate such minute results. Bottles (2) for dropping cobalt and manganese solutions. The best description seems that of *c* (Fig. 25) (natural size), in which the glass of the neck of the bottle is ground

* Paragraph (#2).

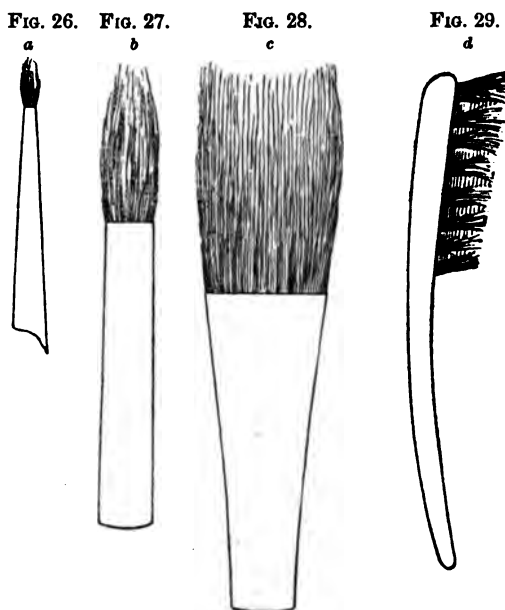
inside and out ; to receive, inside, a tube stopper with pointed end ; and outside, a glass cap ; for by this kind of bottle, drops can be applied without adulterating the solution, which has also, by the device of the cap, the advantage of being kept in a stoppered bottle. These bottles are made of German glass, and sold in London for one shilling each. Bottles (3), 2 inch, German, corked, for containing pure oxides, standard beads, and pattern results of the assay of minerals, &c. Until lately I used to throw away the two latter of these, and would give a good deal now to have some of them, as e.g. the blue phosphoric acid bead obtained at an elevation of 7000 feet, by treatment of sulphur alone in H.P.* These bottles, from their cheapness and hardness, serve this purpose admirably, and the student *cannot* have too many of them. They are sold by Griffin and Co., London, for one penny each, with cork !

(97). BRUSHES (1) soft and (2) hard (Figs. 26 to 29).—(1) Should be of three sizes: *a* and *b* for sweeping assay powders off slabs, balance pans, &c. ; and *c* for sweeping dust off delicate articles, as the inside of the glass case of a balance. These are simply paint brushes, the common kind being better, because softer than those made of sable. The hard brush *d* (natural size) is for scrubbing aluminum and platinum foil with water, and cleansing various utensils.

BREAKING CUSHIONS.—It is well known to Cornish and other miners that you cannot break a mineral with a hammer as well on an unyielding support as on the hand, but the palms of our hands are not so hard as those of the Cornish miners: I therefore use a small pad or cushion, which I place between quartzose minerals and the palm of my hand.

BULBS, GLASS.—Small test tubes answer the purposes of these quite as well, and are (in England) much cheaper, besides being more easily cleaned.

BORERS, CHARCOAL.—Complicated and ingenious borers are sold with the Freiberg apparatus, but they are (for the purposes here detailed) quite super-



Brushes of different kinds.

* Proc. Royal Society, vol. xx., page 453.

fluous, as such small pieces ("mortars") of charcoal are required. A broken drift (Fig. 48) will make a nearly perfectly round hole in charcoal, but the lamp forceps, held tightly together, is perhaps best of all.

BASINS, boiling. (Fig. 35).—These are invaluable little articles, which require no description; the size required is 1 inch diameter, some shallow, and some deep. The best are made in Berlin, having a blue cross over the bottom as a trade-mark. They are sold in London at 3*d.* each. They should not be placed on a stand over the spirit lamp as is usually done, because then the process cannot be properly regulated, but held with the (η) Forceps.*

BLOTTING PADS.—It is always an awkward, and often an impossible, thing to obtain the whole of a fine precipitate, *per se*, from one of the blotting-paper filters used in the laboratory, and, at best, the process occasions an immense loss of time. I have, therefore, cut a piece from one of the common pads of the best smooth white blotting paper, on which I tilt the contents of the basin, after leaving just sufficient water to prevent particles from sticking to the sides of the latter. With the aid of a lens, and the brush *a* (Fig. 26), the most minute dust may be swept from the pad on to the agate slab or balance pan.

CRUSHING INSTRUMENTS.†

CUPELLATING MOULDS.‡

COBALT and MANGANESE SOLUTION BOTTLES.§

CAPSULE (Fig. 30) (natural size) of platinum is useful for covering the basin containing boiling solutions; during which operation I place a flattened

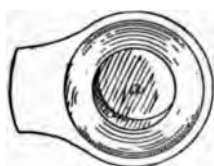
pistol bullet (*a*) in the centre to keep it closed: it can be also used as a tray for detecting nitrogen, &c. || (Fig. 31) (natural size), of horn and polished brass, one of each, for transferring powders or small particles to vessels with contracted mouths, as small bottles.

CLOTHS. ¶

COMPASS.—A compass balanced by Häuy's method (the N. pole just maintained at E. by a magnet) is sometimes useful for detecting traces of magnetism in some minerals. A lady's common hair pin, tempered, magnetized, and swung on its centre of gravity, points nearly E. and W.

COLOR BOX.—The operator may occasionally require one to copy the re-

FIG. 30.



Platinum Capsule, with flat Lead Bullet in it, for covering a dish of boiling water.

FIG. 31.



A Horn Capsule.

* *Vide* Paragraph (98).

§ *Vide* Bottles (2).

† *Vide* Forceps.

|| *Vide* Platinum.

‡ *Vide* Quantitative Analysis.

¶ *Vide* Dusters.

sults he obtains in the shape of beads, minerals heated with cobalt or manganese solution, &c., but it is always best to cork these up bodily in bottles,* though there are things, as some chromatic oxides obtained pyrologically, which he cannot keep, and must therefore copy.

DUSTERS or CLOTHS.—These should be silk rags. Silk remains drier, and is more difficult to soil than cotton. It is also worth washing: the old linings of coats or covers of umbrellas answer admirably. Flannel cloths should be used for cleaning the lens, and chamois leather for an assay balance, and for rubbing the burnished aluminum plate. A *Brush*, as Fig. 28, is, of course, used to “dust” with.

ERASER, INK, is very useful in erasing old names, or formulæ, &c., from the tops of corks, and smoothing the surface for writing new ones on them.

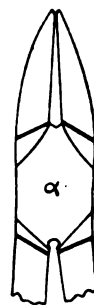
ENVELOPES, old white, should always be kept, as by cutting the corners out squarely, and gumming the one side left, excellent little bags can very rapidly be made, for sending specimens in letters or other like purposes.

EMERY CLOTH, very fine.—A few sheets are required for cleansing aluminum and platinum foil, wires, &c. A small piece on the point of the finger is rubbed on the dirty spot with a drop or two of water.

FLASKS, *metallic*, flat, with screwing cap, for spirits of wine, about 7 × 2 inches, so as to fit in the (a) pocket of the travelling portfolio (Fig. 56); or the spirit-lamp bottle (Fig. 61) may be used instead, as, indeed, it is intended to be.

(98). **FORCEPS.**—These indispensable instruments are divided into two classes, (A) with open handles, and (B) with closed handles. The (A) class, generally made of iron or steel, consisting of a couple of levers acting against each other on a common fulcrum, have immense gripping power, and little or no delicacy of touch. The application of the first quality may be so extended as to almost obviate the present use of the small hammer and open anvil for crushing minerals, as follows: The (a) Forceps (Fig. 32)† is in common use with dentists; its powerful jaws are open at the base but meet towards the point (unlike commonly-made forceps, which will not close properly), where the fragment or crystal is to be placed on the agate slab,‡ the forceps being held in the right hand with the open point resting on the agate slab on each side of the mineral: first and middle fingers below and *outside* the left handle; third and little fingers below and *inside* the left handle; thumb above, where the two handles join; right handle resting firmly against the hollow of the hand; tip of the first finger of the left

FIG. 32.



Forceps.

* *Vide* Bottles (3).

† Mr. Buck, of Holborn Viaduct, sells most of these forceps, beautifully made of case-hardened steel, for 1s. 6d. each.

‡ Paragraph (92).

hand placed over the mineral on the point of the forceps, to prevent any small pieces flying out. I have crushed pieces of *corundum* easily thus, and with care no more of the powder will be lost than by the use of Abich's mortar,* as may be ascertained by a balance; with the utmost care 1 per cent. will be lost either way. (β) Forceps (Fig. 33), also a dentist's implement, is used for nipping off crystals or projecting fragments from a mineral. (γ) or Pyrologist's Forceps (Fig. 34) is the modification of a peculiar leather-worker's implement I have seen. It combines the uses of (α) and (β) Forceps, and adds, besides, a hammer, anvil, a flat part *a* for straightening platinum wires, &c., and a round part *b* for rubbing out the creases in platinum or aluminum foil; while it is easily packed. It is a very useful instrument, but must be made to order; for those sold in leather-workers' shops have serrated jaws, which would never

FIG. 33.

(β) Forceps.

FIG. 34.

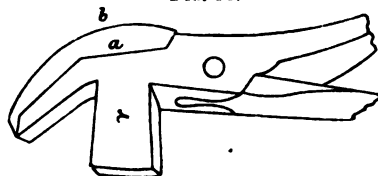
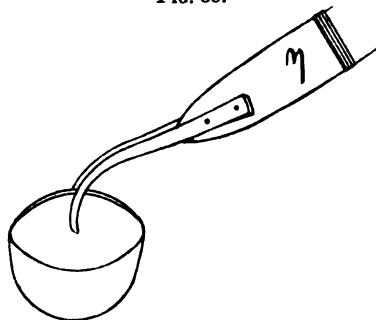
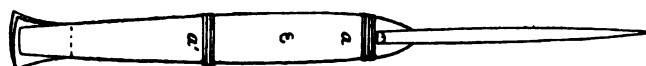


FIG. 35.



Hooked Forceps, holding a porcelain dish for boiling substances in water.

FIG. 36.



Forceps, showing the wire strapping slipped up.

do, as particles and powder of different minerals would remain there and adulterate a fresh assay. To use it for smoothing foils, the foil is placed on a firm table and covered with a piece of strong calico cloth; the (γ) Forceps is then taken in the right hand with the forefinger pressing against the hammer, which is held upwards, and the round part *b* rubbed strongly backwards and forwards over the cloth, after which the foil will be found underneath quite smooth and fit for use. (δ) Forceps (Fig. 38) is for making the ring on platinum wire upon which beads are to be formed. It is found in all iron-mongers' shops, but the legs are never perfectly round, which of course they should be, though tapering towards the points, to correspond with the dia-

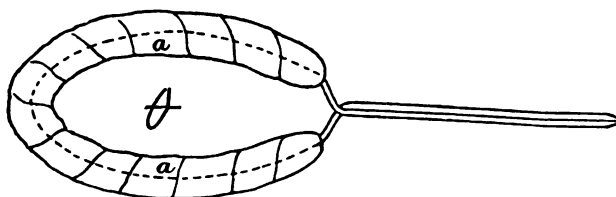
* Paragraph (95).

meter of the ring required: they should therefore be made to order. In class (B) the forceps, also called pliers, are generally made of German silver or brass. (ε) Forceps (Fig. 36) is the shape I use; the dotted lines show the base where the legs are joined together. The brass wire binding *a' a* enables the pliers to be used as platinum wire *holders*, for which purpose they answer admirably, as a *firm* hold is *not* required, while the constant extrication of the wire *is* required.* Yet we actually find it recommended in many modern chemical works to *fuse* the wire *into glass*! When it is required to pick up very small objects, the legs, on relaxation of the fingers, should not spring back too far apart; in this case a smaller binding, as at *a'*, is applied. The inside of the tips of the legs can have a small circular space filed lengthways to fit the platinum wire. (ζ) Forceps, with platinum tips, commonly called "platinum tongs," are too well known to require description; they are considered an indispensable part of this apparatus for holding fragments to be fused, &c.; but a platinum wire .03 inch thick, and bent as in Fig. 49, so that heat may be applied on all sides, will be found to answer the purpose of holding such fragments for fusing or roasting, &c., much better, as the tongs conduct away too much heat, while they absolutely ruin many pyrochromatic reactions, and heat can only be applied to one side of them. (η) Forceps (Fig. 35) for holding basins containing the assay in distilled water over a spirit-lamp flame. Boiling (a boric acid bead containing oxidul balls, for instance) is almost as delicate an operation as the manipulation of the assay with the pyrocone; the moment the water begins to boil, the basin must be raised above the outermost tip of the spirit-lamp flame (which should be as small as possible), or else the water will either boil over, or the assay begin to "spirt" out; probably both things will happen, and in either case the assay is most likely spoiled. The platinum capsule (Fig. 30) lessens the risk of this, but by no means obviates it. Now it is simply impossible to prevent these accidents if a wire support for the basin is used, as *a* (Fig. 5), which is usually done. There is, therefore, no loss of *time* occasioned by holding instead of resting the basin, but very much the reverse. The boric acid assay must, in short, be kept *just* boiling, and no more, until all *else* is dissolved. (θ) Forceps (Figs. 20 and 37), for detecting the sublimes of volatilizable metals fused on platinum or aluminum plate, may be precisely the same as that figured (Fig. 36), with the legs of steel, which should be polished with fine emery-cloth and burnished before use. But a much better description of forceps for this purpose is that shown in Fig. 37, or (θ) Forceps, which remains closed by an oval spring handle, covered with listing to enable the operator to hold it when hot. The whole is made of steel, the legs *b* being brightly burnished. A side view of the (θ) Forceps is given in Fig. 20.

* Vide Paragraph (129, c).

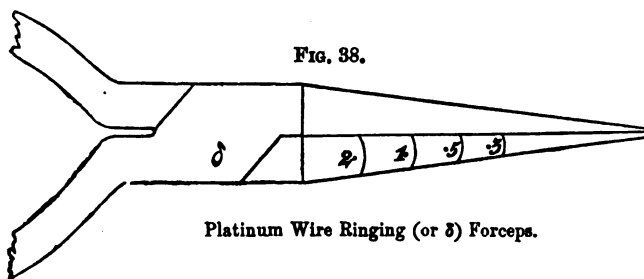
(κ) Forceps are only used (as they were devised) for the Berzelius lamp; they also are similar to those figured (Fig. 36), only made more coarsely of iron, with

FIG. 37.



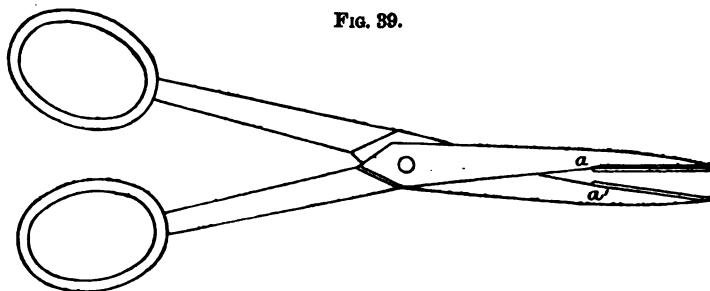
Pressure-opening Steel Forceps for holding aluminum plate.
a. The handle covered with felt or flannel cloth.

FIG. 38.



Platinum Wire Ringing (or δ) Forceps.

FIG. 39.



broad instead of pointed tips to the legs. I use instead of them, the *Scissors-Forceps*, or Pyrological Scissors (Fig. 39), which I have found extremely convenient, as combining the use of two implements in one.*

(99). FILES are useful for many purposes which need not be here enumerated: they should be the smallest procurable, and of three kinds: (α) triangular; (β) rat-tail; and (γ) flat.

GLASS MEASURE (Fig. 40) is sometimes useful in qualitative examinations for taking approximately a certain quantity of powdered oxide; evidently a very rough, but at the same time a very rapid way of estimation. It consists of a small cylinder of solid boxwood graduated as in the figure, with a piece of

* Vide Paragraph (105), art. *Scissors*.

cork fastened to the end so as to tightly fit a glass tube passed over it. The tube I use is .2 inch diameter, and the divisions on the side of the piston .125 inch each. The following table shows the weights of one division of (apparently) equally fine powder of different oxides, loosely filled in, but exactly level with the top surface of the tube.

	Mgs.		Mgs.
AgO	102.7	Galena	207.5
BiO ₂	57.7	Lime (caustic)	47.5
Calcic carbonate (stalactitic)	66.0	PbO	175.2
CuO pure	74.3	Pyrite	132.5
Cuprite	175.0	Realgar (natural)	89.0
Copper pyrites	111.7	SbO ₂	74.5
„ glance	153.5	Stibnite	91.2
Fe ₂ O ₃	61.5	SnO ₂ (pure)	93.5
Gypsum (granular)	69.0	Sulphur	73.2
„ (crystalline)	43.3	Tin oxide (natural)	193.0

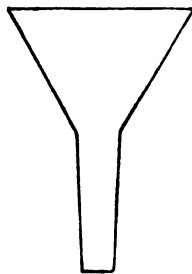
Harkort seems to have adapted this implement (from the old method of obtaining a charge of gunpowder) to a means of measuring the quantity of “granulated lead” (*probir blei*)—deposited on metallic zinc from the acetate—for the cupellation of silver, &c., in which use each larger division holds 100 mgrs. of lead, and each smaller one, one-fifth of that.

FIG. 40.



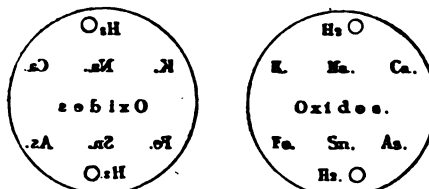
A Glass Measuring Tube.

FIG. 41.



A Glass Funnel.

FIG. 42.



Glass Slab, having the formulæ of oxides, &c., engraved backwards on the under side, so that the upper surface (where they are to be placed or kept) may be smooth.

GLASS FUNNELS (Fig. 41).—A couple of the smallest size procurable (about double that of the figure) are useful; one for filling spirit lamps, the other, vessels with distilled water.

GLASS SLABS, for putting small portions of oxides, dry reagents, or drops of water ready for use. I made mine as in the figure (Fig. 42), by scratching the initial letters of the substances most likely to be required with a diamond,

backwards on the back of the slab, so that when that was turned over the words could be read straight *through* the glass, thus preserving a smooth surface for placing pastes, &c., each, of course, over its own name. Half a dozen of these would be very convenient on a pyrological table, and they have the further advantage of, in a manner, labelling the substance put away from one day to another. Mine are made of common window glass, but German, i.e. leadless plate glass, would be best. Care must be taken, however, that the red-hot bead does not touch the surface, as it fuses a hole, taking up some glass, which adulteration need not be feared with agate slabs, or possibly with German glass ones. They should have a box, with shelves, so as to be put away separately.

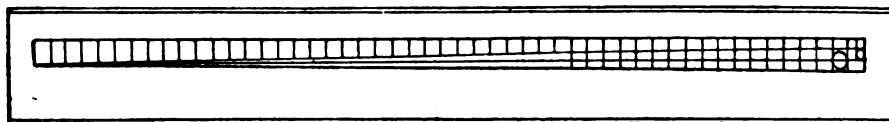
GEOMETRICAL PENS, old (*vide* Fig. 63), make excellent *holders* for platinum wires, by the clamping screw of which they are easily made tight or loose.

GUM ARABIC is always useful, especially to the traveller, in labelling bottles, sealing up paper packets of powders, &c. By far the most portable gum is prepared by a process not known hitherto. The fluid gum is poured into a wide-mouthed bottle having a hollow glass stopper for a bone or ivory stick. The open bottle with the fluid gum is placed in a moderately hot oven until enough of the water has evaporated to render the gum of the consistence of a *jelly*. If the stopper be now replaced, the gum will keep *in that state* for months, and is, moreover, very strong. It can thus be carried in the pocket.

HAMMERS are little used by me, and that attached to the (γ) Forceps (Fig. 34) is quite sufficient for all purposes. A geological hammer does not come within the scope of these descriptions, though of course it is indispensable to the *Mineralogist*.

IVORY SPOONS (Fig. 43), as are supplied with the Freiberg apparatus, should be two in number; one for qualitative operations.

FIG. 44.



Harkort's Scale, for measuring the diameter of small metallic balls.

FIG. 43.



Inside of an Ivory Spoon.

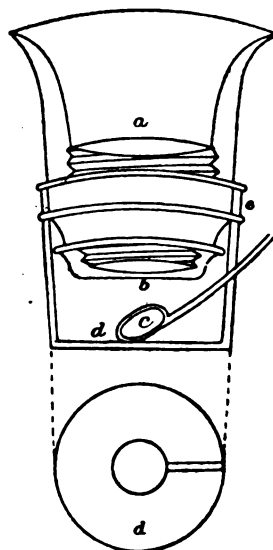
IVORY SCALE (Fig. 44) was devised by Harkort for measuring the diameters of gold and silver balls, derived from cupellation, but too small to weigh; the weights of these being proportional to the cubes of their diameters. This is evidently an operation of quantitative analysis; but I use this scale, made more

roughly, and with an extra converging line, for determining the diameters of anhydrous borate, balls of earths, &c.,* which appear to differ according to the *nature* of the compound; or, more strictly speaking, according to the attraction, or want of attraction, these may have for chemical water.†

IRON SHEETS, as thin and smooth as possible, are useful for taking out the creases which soon form in aluminum or platinum foil, which is placed between these on a hearthstone or other solid ground, and the upper iron sheet beaten with a hammer, when the foil will come out as smooth and even as though it had been rolled.

(100). A LENS, with reflecting collar.—Next to the pyrogene itself, the lens is the most important of pyrological implements. Nothing should be examined without it, as small substances generally appear of a different color to the unassisted eye; the traveller should therefore have a spare one in case of accident. The common shape used by watchmakers is far more efficient and handy than that usually put up in blowpipe cases, which has two glasses moving on a joint outwards or inwards, eyeglass fashion. The advantage of the latter arrangement is supposed to consist in the fact that you can use, if required, only one of these glasses; but as the object is to obtain as high a magnifying power as possible compatibly with the size of the lens, the advantage of having half that power is no advantage at all. It is also inconvenient to open and shut such glasses when required for use, while the fact of the eye being left unshaded is a great *disadvantage*. Fig. 45 explains the other kind: it contains two glasses, not plano-convex as in the first described, but each doubly convex. These can be taken out if required for cleaning, by unscrewing the parts at *a* and *b*. The best way of using it is to apply the broad end firmly to the eye (but not to *stick* it there, as the watchmakers do), and then bring up the object in a slanting direction, *opposite* the light, as at *c*, until the focus is obtained. *d* is a circular collar made of steel, polished *inside*, with a wide opening towards the light, a narrow opening at the back and a round opening at the bottom to admit rapidly the wire and bead. This collar is intended to reflect and concentrate the light upon

FIG. 45.



Lens with Reflecting Collar.

- a* Upper lens.
- b* Lower ditto.
- c* The Essay.
- d* Floor of Reflecting Collar.
- e* Slide of ditto.

* Paragraph (107, *a*).

† *Vide* Boric Acid, and the several heads.

the object. It should be made to fit round the lens at *e*, so as to be easily turned there, or be taken off if required. To view objects by *transmitted light*, turn round the collar so as to shade the upper light from the object, which is then placed over the hole at the bottom, and the light seen *through* it; this is especially useful in cases of *opalescence*.

MICROSCOPE, *simple portable*.—Although a good lens answers most purposes of a travelling Pyrologist, yet he should not be without one of the beautiful half-guinea achromatic microscopes, which, from their cheapness combined with perfection, seem to be of German, not English, manufacture. It magnifies about 120 diameters, and is packed in a varnished box 6.5×2.5 inches. In many cases, as the examination of phosphatic crystals, viz. the detection of iron in semiopaque magnesian balls in beads or glasses, &c., it is simply invaluable. It has no complicated rack movements, &c., which is a great advantage, as it is not liable to get out of order. It requires, however, a light condenser for viewing opaque objects; a defect in part remedied by holding a small looking-glass at back.

MAGNET.—A small horse-shoe one is very generally useful.

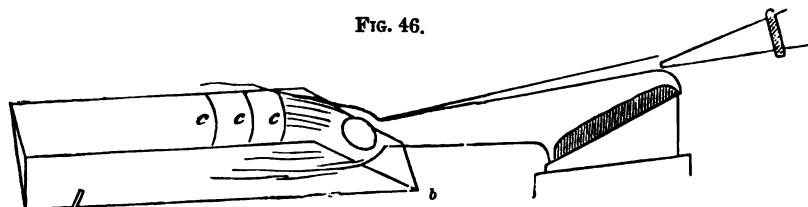
(101). **MORTARS, *charcoal*.**—Fig. 46 shows the manner in which the whole effects of the H.P. may be utilized for substances which cannot be conveniently supported on platinum wire, and require a more reducing heat than can be obtained on aluminum, and the defects of large pieces of charcoal in breaking up and spreading out the pyrocone, and in absorbing and wasting so large an amount of heat, may be avoided. This is by sawing charcoal paste (made according to the subsequent directions) into prisms, about 1.5 inch long by .25 inch deep, and slanting off one end, as at *b*. This is supported by a common sewing needle, stuck into one side, as at *a*. A cavity is scooped at first in the slanting face of the mortar, which, after some use, burns away, as shown in Fig. 47, but no fresh cavity requires to be scooped out, as the assay, being hotter than the surrounding paste, burns a place for itself, while the great advantage is obtained by the operator of being able to instantaneously cool and examine the assay at any time, by dipping the whole in a cup of water.

The following directions for making charcoal paste are from the fourth edition of Plattner*: "Starch paste, the best binding material, is prepared from one part, by weight, of starch meal, and six parts of water. The starch is stirred to a thin paste, in an earthen vessel, with a little of the weighed or measured water, and the rest of the water is poured, boiling hot, upon the paste, and the whole briskly stirred with a beater, until all the meal is converted into paste. To prepare blowpipe coals, this paste is rubbed in a porcelain mortar

* American translation, by Cornwall, p. 19.

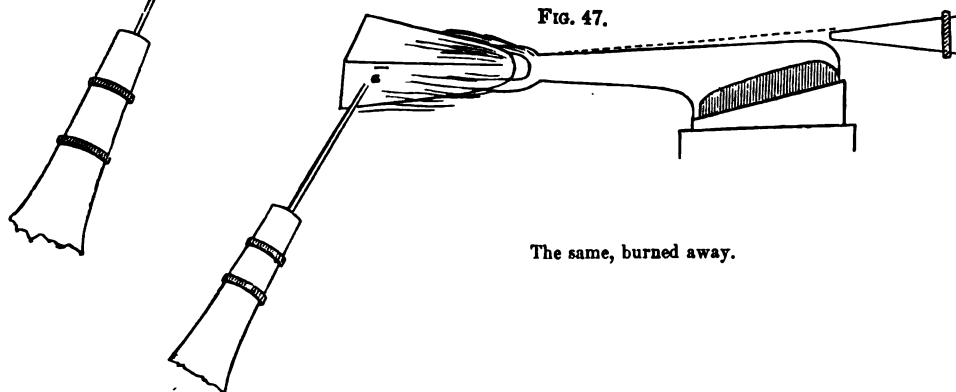
with successive additions of charcoal dust, until the mass in the mortar becomes too tough for any further admixture of charcoal dust. Enough of charcoal dust is then kneaded in with the hands to render the whole mass stiff and plastic, and it is then worked thoroughly. This mass is made into the required shapes

FIG. 46.



Charcoal Mortar, with Assay, held on a needle in a crochet-holder.

FIG. 47.



The same, burned away.

in wooden formers, and allowed to dry gradually and thoroughly. The dried shapes are then heated to low redness, in a covered porcelain crucible, so as to char the binding material, over a spirit lamp with double draught, or a gas lamp. The charring is complete when combustible gases cease to issue from beneath the cover, and when, on raising that, the coals in the upper part of the crucible are perceived to be at a low red heat: the crucible is then removed from the fire, and allowed to cool with the cover on. The coals have been properly prepared when they ring like ordinary good charcoal when thrown on the table."

I have found, however, that really good charcoal, such as that used by Government for making powder at Waltham Abbey, is preferable to this paste of Plattner's, as on aluminum plate at any rate, more heat is retained by it round the assay, and that, consequently, quicker finished; but for the mortars

held on a needle, as in Figs. 46, 47, Plattner's charcoal paste answers admirably. I consider it a great thing to have got rid of the necessity of using comparatively large masses of charcoal, which are far dirtier to handle than mud.

KEYHOLE MORTARS.—For placing on aluminum plate, charcoal mortars are best made by sawing tablets one-fifth of an inch thick with a thread saw,* and then cutting these into prisms, two-fifths of an inch broad, by half an inch long, with a penknife. A shallow hole, about one-tenth of an inch in diameter, is made with the drift (Fig. 48), and the side next the pyrocone cut away with a

penknife to admit the point of the O.P. to the assay, so that the shape of the hole made is that of a keyhole. These mortars burn into an angular shape, very favourable for the treatment of the assay.

PENS, Geometrical, make the best holders for thread saws, &c.

(102). **PLATINUM WIRES.**—The usual thickness is .015 inch, and the ring, made at 5 of the (8) Forceps (Fig. 38), sustains a bead of the proper size for these operations (*vide* Figs. 12, 15). For roasting a fragment, as of limestone or other mineral, however, where there is no fluid substance to revolve, and thus turn its different parts to the heat, an arrangement is necessary by which the back

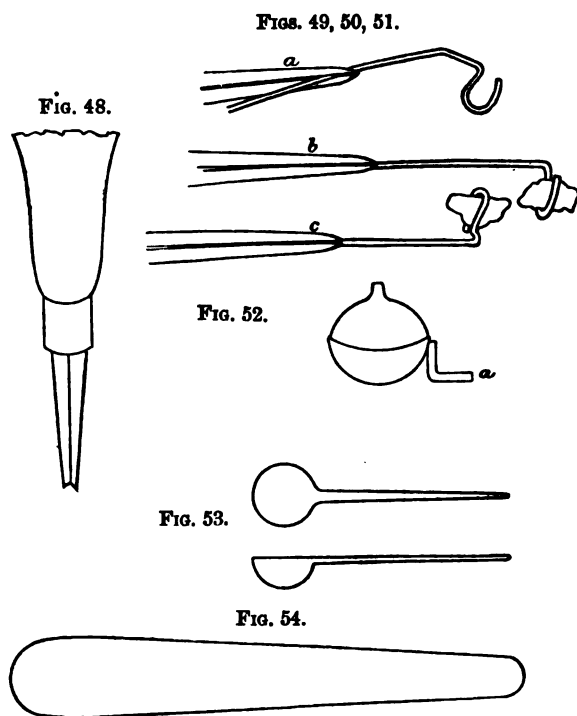


FIG. 49.—Platinum Wire Hook, held in Forceps, showing the way it is bent at a right angle.

- " 50.—Ditto, holding a Mineral Fragment (front view).
- " 51.—Ditto ditto (rear view).
- " 52.—Platinum Crucible for assaying Coal, &c.
- " 53.—Platinum Spoon.
- " 54.—Platinum Spatula.

as well as front of the piece may be duly roasted. On many occasions I tried to use a kind of cage made of very thin wire wrapped about the mineral, which, however, incessantly fell out, and it was some time before I found that a *thicker* wire bent into a *hook*, and that hook bent forward again at right angles to the

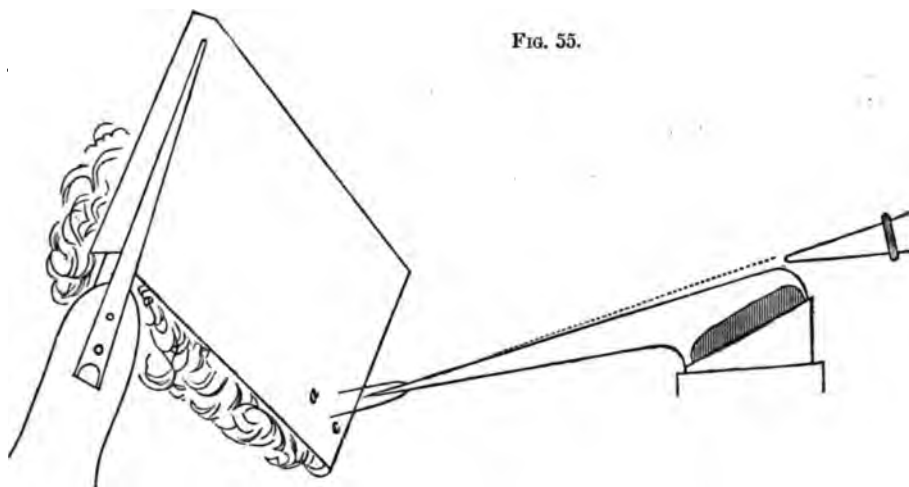
* Paragraph (105), "Saws."

wire, as *a* (Fig. 49), possesses quite sufficient elasticity to hold the fragment with a grip firm enough for the purpose, only it must never be attempted to press the wire *on* the fragment, which is then nearly certain to fall out; but having made the hook broader at the bottom than at the top, the fragment is gently pressed into the top, which has a slight spring in it. The front of the fragment is then presented to the O.P., as shown by *b*, and by turning over the forceps, the *back* is presented, as *c*.*

A PLATINUM CRUCIBLE (Fig. 52) is required for the quantitative analysis of coal, &c., but is also useful to obtain the unadulterated ashes of small organic fragments for a qualitative examination, which in a PLATINUM SPOON (Fig. 53) would be liable to be blown away by the blast. The crucible must be small enough to be weighable with its contents on the smallest assay balance; the leg *a* is to enable it to stand upright, and also for holding it with forceps in O.P.

A PLATINUM SPATULA (Fig. 54) is an expensive and by no means absolutely necessary article, but I have had one in constant use for fourteen years, and it is as good now as the day I got it, and worth intrinsically more, as platinum has now become much dearer. It is invaluable for mixing compounds which would corrode other metals, on the agate or glass slab, and can of course be used on a pinch as PLATINUM FOIL. The foil should be thicker than the usual English kind, and is most conveniently made into a tray about 1.5×1 inch, and held as in Fig. 55,

FIG. 55.



with (ε) Forceps,† the subject of examination being deposited as a paste on its lower lip. The point of the pyrocone must then be applied to the *back* of the tray opposite the substance, and on no account is it to be directed on its

* *Vide* also Manipulation, Paragraph (129).

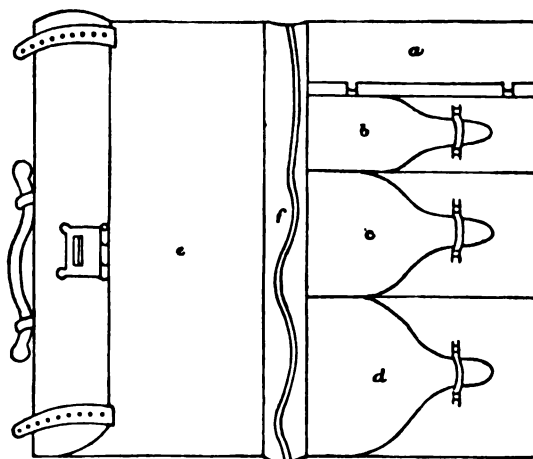
† Paragraph (98).

surface. It will be found that only a certain and normal, not an uncertain and irregular, degree of heat can thus be applied to substances which under pyrological conditions combine with oxygen, or are reduced to a metallic state, and, therefore, that oxidation on the one hand is as exactly regulated as though it had been controlled by a balance, and that reduction on the other hand need not be feared except in the case of the very fusible metals, as antimony or lead, and it is better to roast such sulphurets or arsenurets on aluminum plate (Fig. 20). For instance, *copper pyrites*, roasted as shown in Fig. 55, will be found to lose exactly 17 per cent., and no more, however long or strongly the pyrocone has been applied. The same amount of sulphur is thus volatilized from *copper glauce*. The sublimes of volatilizable substances thus roasted seem to travel up the *platinum* without depositing on it, but thickly coat the *iron* leg of the forceps, each in its particular manner.* To observe slight sublimes, the depositing steel leg of the forceps should be polished bright before use, and then pointed downwards near a window, when the slightest coating will affect the appearance of the shining surface through a lens. Such an arrangement forms also a valuable test for *nitrogen*, which is much required.†

PIPETTES are too coarse a means of removing water in pyrological operations.‡

(103). PORTFOLIO, PYROLOGICAL.—I have packed the whole of my apparatus,

including reagents, two candles, as shown in Fig. 6, and a table pyrogene (*vide* Fig. 11), in one of the common strong official despatch portfolios, with outside lock and hasp (Fig. 56). *e* is a flap of strong stiff leather which prevents hard or cornered articles under it from breaking bottles in the other half of the portfolio. Under this flap I placed the table pyrogene, rolling the tube, reservoir, and jet lengthways round the bellows; the shaft being unscrewed from the iron block,



A common Leather Portfolio, with Lock and Hasp, arranged for Pyrological Purposes.

was placed with it also under the flap *e*, as also a couple of candles next the middle of the portfolio, the twelve metallic rings of which were placed in

* *Vide* Reagents.

† *Vide* Paragraph (119).

‡ *Vide* Suckers.

pocket (*a*), in which also I put a metallic flask of spirits of wine.* In pocket (*b*) were placed the *pliers*, all platinum and aluminum utensils, and a mouth pyro-gene in case of accident to the table one. In (*c*) all the open-handle forceps, and in absence of the (γ) Forceps, a hammer and anvil. In (*d*) the reagents in stoppered bottles, a spirit lamp, and three Berlin basins (Fig. 35); (*f*) is an elastic strap, for holding the paper of an alphabetical note-book. The *lens* I carry in my pocket, in a small leather case, with a thin strap attached to my watch-guard. With such a case the traveller can make *all* qualitative examinations with ease; and, if a practised operator, can make *guesses* within 5 per cent. as to the amount of silica, lime, and the more difficultly estimated oxides.

A PRISM, for examining the absorption bands of beads, &c.—Professor Stokes has favoured me, in a private correspondence, with the following directions and figure: “You want an ordinarily dense flint glass prism, free from veins, with two faces, polished at an angle of about 60° ; the third is left rough and blackened: the ends should be flat, so that it may be taken up and laid down, holding it between the thumb and forefinger applied to top and bottom (Fig. 57): there is thus no occasion to touch the polished faces with the fingers, which would soil them, or the table, which might scratch them. A slit may be extemporized out of a bit of thin metal of any kind, blackened. In using it, by turning the prism round an axis parallel to the edge, the focus is altered. It is convenient, and would not cost much, to have the prism mounted at one end of a tube with a mill-headed stem to turn it in the tube (Fig. 58), and a slit at the other end. An additional luxury (and a cheap one) would be a stand for the tube, so that you could point it to the place, and have both hands at liberty.” “Pocket” spectroscopes are, however, now sold in London for about thirty shillings. These have five prisms and an adjustable slit. In strong daylight, eight of the solar absorption lines are visible through one of them, and *one* orange band at D, when a gas flame, in which a piece of new bread is held, is examined.†

(104). THE SPECTRUM LORGNETTE.

—Since the above was written, I have devised a spectroscope to fit the head like a pair of spectacles, so that the operator can, synchronously, note the spectra of pyrocones or pyrochromes while

* Paragraph (94).

FIG. 57.

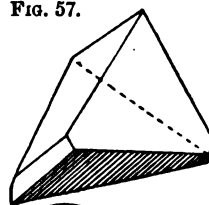


FIG. 58.

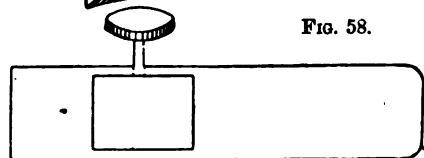


FIG. 57.—A Glass Prism.

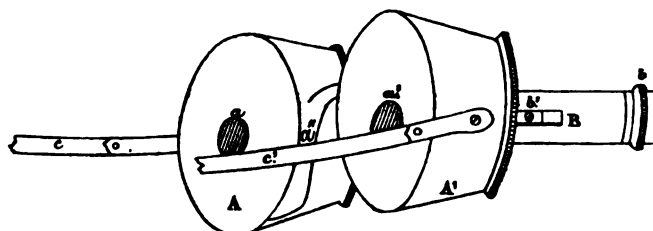
FIG. 58.—A Spectroscope extemporized with 57.

† Vide Paragraph (129, w).

he is producing them. In carrying out this idea, I have been so fortunate as to obtain the assistance of the eminent optician, Mr. Browning, of the Strand.

A A' (Fig. 59) are the barrels or spectracles, made of blackened brass, of the shape shown, and looped together by two padded bridges of brass, one

FIG. 59.



The Spectrum Lorgnette. (One third less than the natural size.)

A A'. The Spectracles; A, Left Barrel; A', Right ditto.

a a'. Their Visional Apertures.

B. The Spectroscope, fitting into either barrel of the Spectracles.

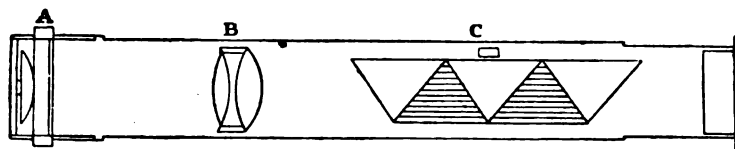
b. The Slit-adjusting Screw of ditto.

b'. The Focus-adjusting Slide of ditto.

c c'. Arms of the Spectracles, embracing the head.

of which is seen at a'' to fit the nose like a pair of spectacles, $c c'$ being the legs (or arms) to go round the head, where they should be held moderately tight with a piece of elastic, so that either eye can be freely opened or shut: $a a'$, the bores of these barrels, are to be, when lined with black felt, about the same diameter as the outer tube of the spectroscope, which can thus be carried in either of them; or, in the spectrum lorgnette made for me by Mr. Browning, $\cdot 4$ inch; but this diameter is lessened at the part next the eyes, or at $a a'$ in the figure, to $\cdot 25$ inch, by a plate with a hole that diameter in it, which prevents the spectroscope from being pushed right through. The bore of the other barrel is left unoccupied, to enable the operator to use that eye *per se*. The spectroscope made by Mr. Browning for this apparatus is only, when closed, $1\cdot 7$ inch long (!), and has therefore been appropriately termed by him "the Minute Spectroscope." I append his description and figure.

FIG. 60.



The Minute Spectroscope. Longitudinal Section.
(Twice the natural size.)

This instrument yields a really fine spectrum when directed towards a bright sky, and shows very distinctly the prominent dark lines of the solar

spectrum. The outer tube carries the slit, which can be removed at pleasure, and is easily adjusted by turning round a ring A. In this tube slides a second tube carrying the small collimating lens B; behind which is placed the system of five prisms C, and an opening for the eyepiece without any lens.

As I have only received the beautiful instrument Mr. Browning has, with a liberality unparalleled in my experience in England, insisted on presenting me with, since the greater part of this work has gone to press, I have been able to make but few experiments with it, and, to prevent disturbing the general arrangement of the work, am compelled to detail those in this place.

The spectrum afforded by the natural pyrocone of a pyrological candle is, in broad daylight, continuous, but about dusk, or in gaslight, a D line is permanently visible, which is much increased in brilliancy by directing a blast on the candle wick. If, however, the observer place his eye exactly level with the base of a candle flame against a window, when it is less luminous, and elevate the spectrum lorgnette by a gentle upward movement of the head, he will, especially if it be a dull day, and his eyes are good, distinguish the D line simultaneously with $H\beta$, or F of Fraunhofer; but on continuing a gentle movement upwards, the latter soon disappears, in consequence of the increasing luminosity of the whole spectrum, which then renders even D fainter and fainter, till that too disappears, or, as it were, fades into light, just as the stars "pale their ineffectual fires" on the approach of day.

This fact may be due (a), to the overpowering of the brilliant D line by the still more luminous or continuous spectrum of the candle; or (b), to the actual elimination of the substance causing D from that part of the flame. The first hypothesis seems correct; for when the elevation of the spectrum lorgnette is continued so that the uppermost part of the pyrocone is analyzed, dimness again supervenes over the spectrum, and D again appears, but not $H\beta$. The hypothesis of luminosity by pressure seems to account satisfactorily for this spectroscopic behaviour of the candle pyrocone, for the upper (1) and under (2) parts of such a cone are just the places where least molecular pressure would be exerted; (1), self-evidently; and (2) because, the pressure being exerted from *below*,* by the rising gas, would of course be in an inverse ratio to the rapidity of the ascent.

If we thus examine a spirit-lamp pyrocone, especially in damp weather, the D line is exceedingly brilliant (the general spectrum being non-luminous), but much more flickering, and less steady or defined, than that afforded by the candle. These facts appear so evidently explainable respectively by the diminution and increase of pressure, that this latter might be almost measured.

* Paragraph (74).

The spectrum of a coal-gas flame is continuous. It is obvious to the operator, after a little practice, that the spectra afforded by some substances, as e.g. lime, *withelite*, platinum, *differ according to the position the fragment occupies in the pyrocone.*

About a year ago I wrote to Professor Stokes, informing him of the mode I had devised of obtaining the orange-red coloration from lime, which I have called the Ellychnine pyrocone (91), and stating my belief that the phenomenon is due to the decomposition of the "flame," not to the lime, which is thus incombustible. This hypothesis certainly seems confirmed by the fact of two other so heterogeneous substances as barytic carbonate and platinum affording the *same lines* (apparently C (or H α), D, and the green line of calcium), when those are heated to whiteness in O.P., and suddenly, in that state, approached so as to touch the wick.

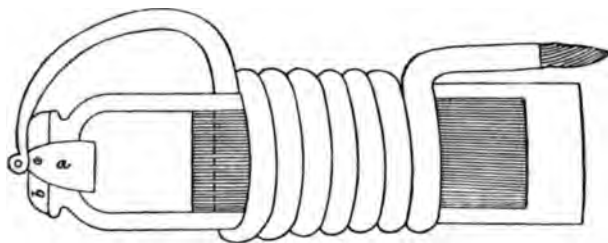
PAPER.—Sheets of clean *white* paper should always be at hand for crushing coarse powder finer, or softish minerals into coarse powder between agates,* as well as for other purposes. The backs of old letters answer these admirably.

(105). SPIRIT LAMPS are quite indispensable, and so often required, that the traveller should have a spare one to fall back on. They are made of metal and of glass, the latter being far preferable, as the quantity of spirit can be easily ascertained. The German bottles used to be made very simply by inserting a brass tube, about 1.25 inch long, with air holes, which holds the wick, and has a cap at its top, through a cork half that length, and then inserting the cork firmly into the neck of the bottle; but the cork is sometimes apt to catch fire if the cap does not cover it properly. The English kind is more complicated, the wick-carrier *screwing* into a brass socket, which again is cemented to the neck of the bottle. This is a bad arrangement, as, once out of order, it cannot easily be repaired. The difficulty in both kinds is, of course, to have some *movable* arrangement by which the spirit can be poured into the bottle, which shall be capable of being stoppered, and not allow the flame to communicate with the bottle, which would thus be broken. To obviate this difficulty, I have devised a spirit lamp-bottle, as shown in Fig. 61, in which a glass stopper (*a*), previously ground and fitted to the known diameter of the throat of the bottle, is left inside that, before it is quite finished. This stopper has a small hole at its apex or narrow end, to which is attached or sewn one end of the cotton wick, which, therefore, when not in use, is pulled completely out, thus jamming the stopper firmly into its place; while the ends are wrapped and tied round the bottle, to preserve it in travelling. A small circular ring or washer of porcelain is, previous to use, placed over the mouth of the bottle to prevent it from being cracked by sudden

* *Vide* Paragraph (92).

heat. This arrangement combines a lamp with a travelling bottle, in which a considerable supply of spirit can be taken without fear of evaporation. A bottle with a brass screwing cap, the only other way of effecting this, is apt to become jammed, and utterly immovable without breaking the bottle. The stopper may also be fastened in the throat of the bottle by a stout wire placed across.

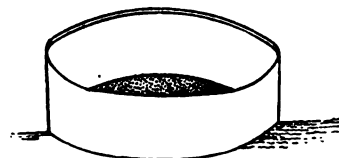
FIG. 61.



A Bottle Spirit-Lamp. The wick, attached to the stopper *a*, pulls that tightly into the neck of the bottle for travelling, and is then wound round it to preserve it from breaking.

b. Porcelain Cap, to prevent the heat from cracking the glass.

FIG. 62.



A Brass Sieve, for filtering minerals like *Jeypoorite*, &c.

A SIEVE, of brass or German silver, round, 1·5 inch diameter by ·5 inch deep, with holes the size of a common sewing needle (Fig. 62), is very useful.

SAWS, THREAD, are indispensable for sawing "mortars" out of charcoal, used as described in Paragraph (101). Six should be taken, and can be used by fastening one end in a geometrical pen.

They are required for sawing up pieces of charcoal or charcoal paste into "mortars," &c. A surgeon's pocket saw can also be conveniently used here.

STEEL PENS can be laid aside after writing, without the ink crusting over and spoiling them, by simply *waxing the back of them*, to which the ink then will not stick.

SCISSORS, PYROLOGICAL.—A pair is required for trimming the candle or lamp wick; also for cutting brass wire for binding forceps of the B class, &c. The points should have raised sides, as in Fig. 39, to act as pincers for pressing the wicks together, &c. Appertaining to the German Berzelius blowpipe lamp, are a pair of scissors, *and* a pair of forceps for trimming the wick. These two implements may, however, be combined in one, made as follows (Fig. 39). As far as *a a'* from the left, are ordinary scissors; but from *a a'* to the points, the edges are removed, and replaced by two flat surfaces. From *a a'* also, to the points, two small flanges, of steel or iron, are turned upwards from the legs on one side, so as to form in that part a coarse pair of pincers or forceps, which, when the scissors are closed completely, must be in contact; that is, from *a* to its point must coincide with the part from *a'* to its point. It is evident that

the part from *a a'* to the base, or thick part of the blades, will answer for *cutting* the wicks; and, from *a a'* to the points, for compressing them. I asked Mr. Buck, of the Holborn Viaduct, to make me such an instrument, and drew a figure of it in his shop to that end, but, to my great disappointment, he said it could not be done.

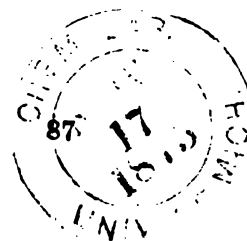
SPONGES.—Pieces of old sponge are useful in many ways. They should not be larger than a turkey's egg.

SUCKERS of white blotting paper are used instead of a pipette for absorbing small quantities of water, or rather water in which boric acid is dissolved, from balls or residues left in basins after boiling. These suckers should be about an inch long, and rolled up to a point like a spill. They can be made as required, or a box full of them may be kept ready, and some may be colored blue and red with litmus, in order to see, while absorbing it, whether the solution is acid or the reverse.

TEST PAPERS, red, and blue, and yellow.—Plattner gives elaborate details of the manufacture of these; but they are so cheap and common now, that no one would think of making them. They should be kept shut up in the tight-fitting boxes in which they are sold.

TUBES, TEST.—The smallest kind only should be purchased instead of the "nests" of different sizes in which they are sold, as the larger sizes are of little or no use for pyrological operations. These small test tubes answer all the purposes of the "bulbs" or "matrasses" used in Germany, and have the great advantage over those of being much more easily cleaned. Common glass tubes sealed at one end are too thick, and do not answer well. I never use *open* glass tubes now, but examine sublimates on aluminum or platinum trays, as in Figs. 20, 55.

REAGENTS.



REAGENTS, AND HOW TO USE THEM.

(106). Plattner gives a list of no less than fifty reagents, including the violent unportable acids, but it must be remembered that the alkaline earths, for instance, were (and are) supposed to be only detectable by "the wet way,"* and that the very remarkable and differing behaviour of these and many other oxides in *boric acid* has enabled us to dispense with a great many of those reagents, while the replacement of the mineral acids in this apparatus, by the more powerful *phosphoric acid* under O.P., gives us at once a solvent as portable as it is strong.

Following is an alphabetical list of pyrological reagents :

Arsenic acid. *Arsenicobalt solution.* *Alumina.*
Boric acid. *Borax.* *Borate of lime.* *Baryta water.*
Cobalt solution. *Calcic chloride.* *Cupric oxide.* *Cobalt pyrooxide.*
Ferrous sulphate. *Ferric sesquioxide.*
Gold metallic.
Lime carbonate (in fragments). *Lime calcined (in fragments).*
Manganese solution. *Manganicobalt solution.* *Magnesium sulphate.*
Phosphoric acid. *Pyrophosphate of sodium.* *Phosphate of zinc.* *Calcic pyrophosphate.* *Potash caustic*
Potassic carbonate.
Sodic carbonate (fused : in fragments). *Sodic hydrate.* *Silica (in fragments).* *Sulphur.*
Water distilled. *Water chemical, in boric acid.*
 [Those in *italics* are seldom required, and need not be taken in travelling.]

Besides these, the operator should have a set of pure oxides (of as many metals as he can obtain at Messrs. Griffin's, whose name is a guarantee of purity), in the small penny bottles described.† These are entered here, because, by showing the reactions of the pure substance, when the problem is to discover it in combination, they in a manner act as reagents.

ARSENIC ACID.—Obtained as a white powder by oxidizing common arsenic with hydric nitrate. Should be kept in a stoppered bottle, as it rapidly absorbs moisture, becoming eventually liquid in a common bottle and attacking the cork, of which it forms a black solution. *Use.*—Its chief use is to detect *soda*, or *potash* in presence of soda, by the different reactions of those alkalies on its combination with boric acid and cobalt oxide.‡ It also serves, in combination with phosphoric acid, to attack and oxidize platinum, and thus to obtain pyrological reactions from that metal.§

ARSENICOBALT SOLUTION.—Made by adding one-third of arsenic acid solution

* "Kalkerde und Talkerde Kann man nur mit Hinzuziehung des nassen Weges ausscheiden und jede dieser Erden für sich der weitem Prüfung vor dem Löthrobre unterwerfen."—Plattner's 'Probirkunst mit dem Löthrobre' 4 Auflage. 1865. p. 185.

† Paragraph (96).

‡ Vide Paragraph (69) 6).

§ Paragraph (23, b).

to two-thirds cobalt solution (nitrate); should be kept in a dropping bottle,* and shaken before use. *Use*.—It seems to give different reactions to those of simple cobalt solution, of which some are the following:

	(a) After Application of Heat.	(b) Dried near Spirit-Lamp Flame.	(c) In the Peroxidizing Pyrocone.
1. Lime	Pink	No change	1st, Black; 2nd, Grey-white.
2. Ditto + Fe_2O_3	Light brown	Brown and pink	Light grey.
3. Alumina	No change	Faint pink	Blue.
4. Al_2O_3 + Fe_2O_3	Brick red	No change	Lilac; O.P. grey.
5. Fe_2O_3	Bright red	Raw liver color	Flesh colour; O.P. black.
6. Silica	No change	Faint pink	Pale mauve; O.P. purple.
7. SiO_2 + Fe_2O_3	Bark brown	Cooked liver color	Reddish-white; O.P. dark grey.
8. SnO_2	No change	{ Bright pink when very hot }	Red-mauve; O.P. emerald green.
9. SnO_2 + Fe_2O_3	Flesh color	{ Peach pink when very hot }	Grey, with greenish tinge; O.P. black, with ditto.
10. ZnO	No change	Brilliant peach	{ Bright green front, blue back; O.P. fuses to dark green.
11. ZnO + Fe_2O_3	Brown	Chocolate color	Black, with green spots.

Some of these changes are, it is true, due to the sublimation of A^2_2O_3 , which appears as a white efflorescence; but that fact does not make them less valuable, if, for instance, they serve to show us alumina in presence of iron, which simple cobalt solution does not. The above table was drawn up in 1871.

ALUMINA (symbol, Al).—*Uses*.—It serves (a) to separate silica from lime in boric acid, and (b) as a detective for potash.†

(107). BORIC ACID (symbol, HB).—Obtained by treating borax with hydric sulphate, but, also ready crystallized, very cheap and pure from any good chemist. If required fused, i. e. in the shape of *beads*, it should be kept in a stoppered bottle, but the crystallized acid can be kept in a corked bottle. The bottle for using it from should be wide-mouthed. *Preparation and Character*.—This is the most important of pyrological reagents, and its value is enhanced by the fact of its cheapness (3*d.* an oz.), its portability, and unliability to be injured by damp, &c. When *fused* in the ordinary way (in a platinum dish) as sold by our chemists, and with the German blowpipe apparatus at Freiberg, it is utterly spoiled as regards its most delicate and valuable pyrological reactions; for it then no longer forms a clear achromatic glass, but is *opalescent* from its adulteration by *chemical water*, derived from the surface of the heated platinum. If, therefore, it is required in a fused state (which saves a little, but not much, time in operation), that must be done on platinum wire by the pyrogene, and the HB shaken off while red hot, on aluminum plate, in the form of a bead. The best way to prepare boric acid for use, as I found after many trials, is to boil a

* Paragraph (96), Fig. 25.

† Paragraph (69) 25).

saturated solution of the crystallized acid in distilled water, in a Berlin saucer, over a "quick" fire, i. e. no sand or other bath. The water is to be evaporated, the residue being constantly stirred with a glass rod, and desiccated until the water of crystallization has been driven off, but care must be taken not to fuse it. $\text{H}\beta$ then appears as a white uncrystalline bulky powder, not unlike common table salt in appearance. The intumescence is thus got rid of on first heating, and this powder adheres easily to the hot wire (which the crystallized does not), provided the mass be heated with a long P.P. all round the outer surface in the first place; after which no particles will drop. The fusion is then completed in H.P., the glass or bead being every now and then moved rapidly up from near the tip to the base of the pyrocone, by which all bubbles are soon eliminated. It should be fused ready for use in H.P., but the oxides applied to it treated with O.P. In H.P. crystallized boric acid intumescences extraordinarily, like *apophyllite*, the slightest particles near the edge even swelling to nearly four times their size; after this the number of small bubbles, due to gas evolved, makes it look like spittle. While this takes place, a pure green pyrochrome, brighter, but not so dark green as that of copper, with a pleasant aromatic smell, is observed. Before the intumescence is quite over, some small black particles will be seen to appear at this stage; these glow red hot for a few seconds and then disappear into gaseous bubbles, which, from the viscid nature of the substance left, are rather difficult to eliminate, and are best got rid of by a strong coal-gas H.P. The substance now, is extraordinarily vitreous, highly refractive, and, if clear, colorless and free from bubbles, ready for employment.

(107, a). *Uses*.—There are at least eleven oxides, which, either as chemically prepared, or as found in minerals, form, when applied under O.P. to a bead of $\text{H}\beta$ prepared as above described, *perfect Sphericles*, some transparent and colorless, others opaque, some white, others beautifully tinted, but all evidently forming chemical compounds with differing proportions of the boric acid of the bead, and contained within it. *Boric acid* is, so far as I know, the only substance in the world which affords to this treatment such an extraordinary phenomenon. Thus, the certain detection of *lime* and its combinations, for instance, which, before this fact was known (in 1869), was an impossibility with the blowpipe, is now one of the easiest and quickest, one of the most certain, and not far from one of the most important of pyrological reactions. Such minerals, for example, as *Adular* or *Analcim*, being merely powdered and applied under O.P. to $\text{H}\beta$ betray the very next moment the small quantity of *lime*, *alumina*, and *soda* or *potash* they may contain, without any further treatment. In the whole range of chemistry there is no other single reagent which can effect anything like this; and it adds to our astonishment to know, that enough of this one to

investigate the pyrological reactions of the rocks or minerals of a whole county, can be carried in a small phial in the waistcoat pocket. $\ddot{H}\ddot{B}$ is also the best detective for minute traces of free phosphoric acid, as in the *black Tourmaline*; by vesiculation,* it detects a trace of potash; by pyrochromatism, a trace of soda (and by "soda," I mean the substance that can be separated and weighed as such, not that which affords, spectroscopically, the lines D to the ignition of nearly every known mineral); and even, by the *addition* of soda, the presence of itself—boric acid—in a mineral, as in *Tourmaline*, or *Axinite*.

(108). Plattner gives an excellent description of some of the properties of *boric acid* under the head of "borax" (!) † "The borax contains, besides borate of soda, free boric acid, and this has the property of combining with oxides at a high temperature, driving out weak acids; and with the aid of the oxidating flame, disposing metals, sulphur, and haloid compounds, to oxidize; borates of the oxides result, which fuse readily in borate of soda and give a clear glass." Now, it is just this "ready fusion" of the resulting borates which ruins borax (compared with boric acid) as a reagent; but we have besides, ample practical proof of the fallacy of these ideas of "free" boric acid in borax, and "free" phosphoric acid in microcosmic salt; first asserted, apparently, by Bergman, who says of the latter: "The volatile alkali is expelled by the fire, therefore an excess of acid remains in what is left behind." It is a remarkable fact that *metals* oxidized by a P.P.‡ in $\ddot{H}\ddot{B}$, afford perfectly different borates to those formed by the similar treatment of their *oxides*, obtained by "wet" processes, or as found in nature; and it is for some of the former reactions alone, as the separation of copper and lead in an alloy, that this beautiful reagent has hitherto been used. Some metals, as lead and zinc, dissolve slowly in $\ddot{H}\ddot{B}$ to a clear fluid glass by this treatment, but this cannot be a mere mechanical solution of the metal, as, independently of the evident and even violent decomposition which takes place, the solution of the glass again in boiling water is rendered *strongly acid*: the behaviour of chemical or natural borates is given above, but this general difference may be thus briefly stated. Metallic borates are *soluble* in $\ddot{H}\ddot{B}$, under O.P., and again in water, leaving the oxides. Oxidul borates (spherespheres) are *insoluble* in both. Only the oxides of the alkaline metals are completely soluble in $\ddot{H}\ddot{B}$ pyrologically, and hence the value of the latter as a detective agent for them, and also as an alkalimeter; for if a very small trace of soda or potash contained in a mineral or salt be applied to a $\ddot{H}\ddot{B}$ bead, having globules of cobalt, for instance, suspended in it, those nearest the side where the alkali is applied are dispersed and spread over that side as a pink suffusion. If 5 per cent. be added, the sphericles of cobalt disappear, the whole bead is clarified, and assumes a blue

* *Vide* Paragraph (63).

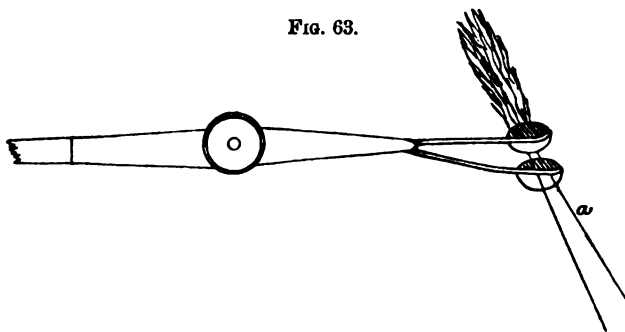
† *Am. trans.*, p. 56.

‡ Paragraphs (29) (208).

color while hot, but remains pink on cooling. If 17 per cent. be added, the bead remains *blue* on cooling, and (in the case of soda) borax has been formed.

(109). If the alkali is *soda*, the fact is easily proved, for a trace (say, fused carbonate) of sodium applied to a $\text{H}\ddot{\text{B}}$ bead in H.P., causes the beautiful green pyrochrome of the latter to be considerably modified, the green tint being now much imbued with yellow; if another trace be added, the pyrochrome is greenish-yellow; and by a third trace it becomes nearly *orange*, no green being visible. If copper be added to a $\text{H}\ddot{\text{B}}$ bead in H.P., its green pyrochrome is made much more brilliant and striking by its combination with the *bluish-green* one of copper, the smallest trace of which can be thus instantly detected.* It therefore seems evident (a) that the green pyrochrome of $\text{H}\ddot{\text{B}}$ can, unlike most others, be *combined* with the colored flames of other substances; and (b) that the modification caused to it by that of *soda* is directly proportional to the quantity of that base dissolved in it. The best way to observe these pyrochromes is to have *two* beads in the holder together (Fig. 63), one bent

FIG. 63.



Two Platinum Wires containing Beads, held in a Geometrical Pen, for observing the Pyrochrome.
a The Pyrocone heating both simultaneously.

over the other, and to direct an O.P. *between* them, when (the upper or under) one, being composed of pure $\text{H}\ddot{\text{B}}$ *only*, the different pyrochrome given to the other by any substance dissolved in it will at once be perceived. They may also be in the same line of fire, provided the pure $\text{H}\ddot{\text{B}}$ glass be in *front*, i. e. next the O.P. This substance is called "Boric Anhydride" in works on chemistry; but that it really contains constitutional (chemical) water, which cannot be separated from it by heat, seems clearly proved.†

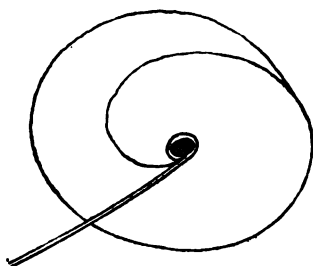
(110). The best reagent for testing the purity of boric acid is *itself*; that is, if we fuse a glass of the acid to be tested on clean platinum *wire*; take it off the ring (by unrolling the wire from it with the fingers when cold); crush it with (a) forceps on an agate slab, and treat a trace of the powder, applied to a

* Vide also Paragraph (258).

† Vide Magnesia.

pure $\text{H}\ddot{\text{B}}$ bead, in O.P.; *any* change, as opalescence, balls, fragments, &c., denotes impurity in the former, while *soda* adulteration yellows the green pyrochrome, and 1 per cent. of *potash* is detected by vesiculation, as follows: The bead while red hot is blown into by means of a mouth pyrogene, having a jet with an orifice *not less* than this (o): in a common Plattner's blowpipe, the tube, when the platinum jet has been taken off, answers the purpose. If the bead be not too cold, the result will be that the whole mass is blown out into a thin clear bubble or vesicle (iridescent, of course, in proportion to its thinness) about seventy times the size of the bead (Fig. 64), thus presenting a very large

FIG. 64.



A Vesicle, formed by blowing with the jet of the pyrogene, through the ring of the platinum wire, into the red-hot bead of boric acid, &c.

surface of the dissolved oxide to be operated on. This vesicle is then held in the operator's open mouth and breathed on strongly, when, if the alkali contained a trace of potash, the vesicle is immediately clouded over with a light blue film, the color of a solution of quinine. If only soda be present, the vesicle will remain clear, but begin to deliquesce. Lithia affords a tarnish like that of breath on a pane of glass, and the vesicle does *not* deliquesce. The pure $\text{H}\ddot{\text{B}}$ vesicle itself clouds over after a few minutes, and by contact with the breath, but its appearance is more white than blue, and if the clouded vesicle be ap-

proached to the flame of a spirit lamp, the coating is not removed until the flame almost touches it and shrivels the substance of the vesicle, whereas a trace of potash causes the cloud to fly as if by magic when the vesicle is even a considerable distance off.

(111). The clouding over of the $\text{H}\ddot{\text{B}}$ vesicle containing potash is proved to be due to the *moisture*, and not the carbonic acid of the breath, by holding a freshly-made one, first in the smoke of an ignited, but not flaming, piece of brown paper, when it remains clear; and then in steam, when it is immediately covered with a white cloud. It is thus evident that a traveller, having *only* a "blowpipe," a candle, a piece of aluminum plate, and a little *boric acid*, may make a considerable number of exceedingly valuable analyses.

BORAX.—I do not know a single case in which sodic diborate can be as advantageously used for detective operations as the reagents I have adopted instead of it, and for which I relinquished its use; but I have given the ordinary blowpipe tables (in the Appendix) in order to have a *multiplicity* of reactions, which is valuable chiefly for the sake of comparison, and, besides, borax is sometimes, and may always, be formed in the course of analysis as

above described.* It is always obtained sufficiently pure in the chemists' shops.

CALCIC BORATE (symbol, $\frac{\text{Ca}}{\text{HB}}$) is obtained by adding a fragment of pure calcined lime under O.P. to a bead of boric acid, and extracting it (in the shape of a ball) from the latter by boiling in distilled water. The lime of this ball will be found to be always $\frac{1}{4.5}$ th of its weight,† so, assuming 50 mgrs. as the general weight of the ordinary HB bead, we have $\frac{50}{4.5} = 11.5$ mgrs. or 23 per cent. of lime required to form a mixture for making *beads* of this reagent; but there is this disadvantage attending such a process, that the chemical water which is always given off from even the most completely and freshly calcined lime in boric acid, is dissolved in the calcic borate *bead*, while it is absent from the calci-boric *ball*,‡ and the more this reagent approaches the anhydrous state, the more strongly it seems colored by certain metallic oxides. *Uses*.—When metallic oxides are added to a HB bead containing a $\frac{\text{Ca}}{\text{HB}}$ ball, they are (except the alkalies) insoluble in the former, but are rapidly dissolved by the *ball* which is thus immediately colored by a chromatic oxide. Iron, especially in the form of protoxide (to which this flux seems to reduce it), is detected in the most minute trace, by the ball assuming a green shade, which is very distinct in the opalescent (for chemical water is sure to be also contained in the mineral or assay) bead. I have in this way detected a trace of iron in (seemingly) pure magnesia, a reagent in a chemical laboratory. Sometimes the mineral itself supplies both the lime and the iron as impurities, e.g. *Sassoline*. $\frac{\text{Ca}}{\text{HB}}$ is also used to decompose silicates of alumina in a HB bead, the alumina apparently combining with it as a *white waxy* ball, and the silica dissipated over the bead as opalescent matter, which is soluble in boiling water, but precipitated as that cools, in a flocculent state.

BARYTA, used precisely as lime (above described) with HB for detecting manganese in presence of cobalt oxide.§

(112). COBALT SOLUTION (symbol, Co. Soln.).—The nitrate is best; and should be as dilute as possible, because the cobalt oxide is apt to be reduced to protoxide and to spoil reactions, as a black or grey-black mass; yet I see it recommended in some chemical works to have the solution as *concentrated* as possible. *Use*.—Cobalt solution is applied in two ways: (a) dropped on the

* Paragraph (108).

† *Vide* 'Qualitative Analysis,' vol. ii.

‡ Unless a number of balls are separately extracted and fused together into a bead.

§ *Vide* Paragraph (230, f).

mineral, *after* that has been well heated, and the fragment then held near a spirit-lamp flame. (b) By applying an O.P., or better, a P.P. to [a]. In the first case the whole of the "earths" (provided they are *white*), with the exception of *lime* and *strontia*, are merely made pink by absorption of the solution; these two, however, turn a deep blue in proportion to their purity, but not so pure blue as that of alumina in [b]: after a short exposure to the air the lime fragments turn green, on the outside, the inside remaining white; the strontia ones brown. The blue coloration is apparently due to the dehydration of the cobalt in solution, by the earth causticized with that amount of heat. When there is evidently only a small proportion of lime in the fragment, as in some silicates, that may be placed on the back of the hand, in order to recognize the lime by the heat imparted by hydration (as Von Engestrom has ingeniously suggested); but I have the scar yet visible on mine, of a hole burned there by a piece of lithographic limestone, which I incautiously thus tested on it. On approaching a spirit-lamp flame with [a], the blue of lime and strontia becomes much paler; the other, now pink earths, including baryta, provided it has not been fused, deepen to a rich carmine, showing that they have not decomposed the solution, the color of which alone is similarly deepened by heat. In the second case [b], the blue calcic and strontian fragments turn black, or grey-black; baryta (according to Plattner), brownish red. Alumina affords the purest blue known, for even ultramarine has a violetish tint beside it: silica, a pretty bluish violet: a silicate of alumina (as *Cyanite*), violet blue. Magnesia alone remains pink. Unfortunately these reactions are destroyed by the presence of nearly every metallic oxide; not merely because the fragment is then no longer white, and therefore does not show changes of color so well, but because the mixture seems to exercise a reducing effect on the cobaltic oxide, under O.P., which becomes nearly black. I tried to remedy this defect by combining with cobalt solution a substance possessing great oxidizing power,* with but partial success; and, after that, manganese.† As it seems probable‡ that there is, in addition to the protoxide and sesquioxide described by chemists,§ at least a third oxide of cobalt, the violet one, it would appear that the charming hydrous chromatic transformations which constitute the utility of this reagent, are due to the comparative power possessed by the substance with which it is mixed, of not

* Arsenic acid. *Vide* Arseni-Cobalt Solution.

† *Vide* Mangani-Cobalt Solution.

‡ *Vide* Cobalt.

§ I possess a book ('Metallography,' by Dr. Blyth, Longman, 1871), which says, p. 39: "The protoxide (of cobalt) is *dark blue*: it consists of 84.38 cobalt and 15.62 oxygen. . . . Moist protoxide gradually absorbs oxygen, and assumes an *olive* color; this is the *deutoxide*; 73 metal, and 27 oxygen. By gradual exposure of this oxide to the air, more oxygen is absorbed, and the *peroxide* is formed: this is *black*, and consists of 80 cobalt and 20 oxygen." The most interesting part of this extraordinary account is, that the "*deutoxide*" contains 7 per cent. *more* oxygen than the "*peroxide*."

deoxidizing, but dehydrating it under O.P., as the case may be. Thus *lime* and *strontia*, rendered caustic by much less heat than the other earths, dehydrate the solution then, by its mere application, which none of those will do. If, however, we continue to apply O.P. to lime or strontia, saturated with Co. solution, their operation under such conditions being of an alkaline or reducing nature, the effect is the reduction of the already dehydrated peroxide of cobalt to the black sesquioxide. *Alumina*, on the contrary, acquires while under great heat, as O.P., very considerable causticity, which it in great part loses when that heat is withdrawn, though it will even then "slake" water with some violence: at the same time it has under these conditions no reducing power, but rather a tendency to impart oxygen: the Co. solution is, therefore, left a brilliant blue. *Magnesia* being very difficultly if at all dehydrated by pyrogenical heat, while at the same time it is a great *passer on* of oxygen (in the manner of manganese, as may be seen from the many bubbles which both of these oxides germinate in a glass of *phosphoric acid* under O.P.), the cobalt in the solution with which its fragment is saturated remains pink (or hydrated) under O.P., and only becomes more red or deeper in color by greater heat. In no one of these cases, of course, is there any *combination* of the substance treated with cobalt oxide, but simply a decomposition of the solution of cobaltic hydrate; if, however, lime or other similar substance be present with *silica*, the latter *fuses* under O.P., and a chemical compound (the silicate) of cobalt is formed, which is blue (but not a pure blue like that of alumina) and glassy. This reaction, which is noticed but disregarded by writers on the blowpipe, is, however, a valuable one; for it very simply and rapidly indicates in such minerals as *Felspar* a large proportion of silica and a little alkali or lime, without which the silica could not have been fused.

COBALT PYROXIDE (symbol, CoO_2) (?) is obtained by treating the black balls of borate of the protoxide in boric acid with P.P., when they slowly oxidize to a beautiful violet colour, from which metallic cobalt can be pyro-electrically deposited on the platinum wire.* The balls or masses are extracted by boiling in distilled water, crushed to a fine powder between agates; that is boiled in fresh water, the water decanted, and this process repeated until no crystals of boric acid are formed in the water by evaporation. Thus prepared, pyroxide of cobalt is a beautiful violet powder, having evidently strong pigmental qualities; it does not stain or adhere to paper like graphite as the protoxide does. *Uses*.—It is chiefly used for detecting alkalis in H_2O and can be advantageously employed in making the solution of the nitrate, as it is more rapidly dissolved than the protoxide.

* *Vide* Cobalt.

CALCIC CHLORIDE (symbol, CaCl).—Chiefly used as a detective of the proportion of carbon in ignited gases, a preponderance of that element turning its red-orange pyrochrome into a bluish-purple. It also combines by fusion under O.P. with silica, into hard rock-like masses, which are useful in analysis as a calcic silicate of known proportions.

CUPRIC OXIDE (symbol, CuO) is useful when dissolved in a glass of hydric phosphate, for detecting sulphuric acid, chlorine, and fluorine, in substances.* It also detects free chlorine in some cases by having its green pyrochrome changed to blue by the latter, according to the observations of Bergman and Berzelius. Also used for detecting boric acid.

FERROUS SULPHATE.—A cheap and portable reagent, which may even be procured in an Indian bazaar. It precipitates silver from the nitrate solution as a beautiful metallic silvery "shower," best seen in a test tube; a fact not generally known. The precipitate it affords with a water solution of phosphoric acid beads in which gold or silver has been dissolved, is very curious, having a white chalky appearance. Some pure crystals of this reagent should always be kept.

FERRIC SESQUIOXIDE (symbol, Fe_2O_3) is used for detecting alumina in presence of silica.†

GOLD, METALLIC, may either be kept in leaf in a bottle, and melted to a ball in HB (in order to free it from any silver or copper, &c.) as required; or kept in balls of 50 or 100 mgrs. each. They are used to detect small proportions of arsenic in metallic combination, as in *Jeypoorite*.

(113). **LIME** (symbol, CaO).—One of the most important of pyrological reagents. It is most easily and best prepared by treating a fragment of clean eggshell, held by platinum forceps, in O.P., until it glows = (a). Several fragments thus prepared can be conveniently broken into pieces the diameter of a pin's head, and preserved in a bottle for use; but this reagent, as indeed all, should not be crushed finer than fragments, as powder is apt to be contaminated with siliceous dust or sand. I obtained lime, beautifully pure, from the *surface* of blue limestone rocks, at Mussoorie, India, which had evidently been partly dissolved, I suppose, by the united action of the solar heat in summer, and the snow water in winter, and lay in yellow (but this color was not due to iron sesquioxide) drippings or droppings, as a sugary cake-like mass. Calcined and ground into a paste with the assay, the mass held on a platinum ring, will betray in the latter, when covered with a good candle H.P., any *chlorine* (as a black patch, apparently chloride of carbon) next the current of ignited gas;

* *Vide* those heads.

† *Vide* Alumina.

or *fluoride* of carbon (?), as a *green* semi-metallic patch, in the same way. Lime is also used for making anhydrous borocalcic balls.*

MANGANESE SOLUTION (symbol, Mn. Soln.).—On heating the mineral *Barytocalcite* in O.P. part of it immediately turns a pale green color, due, according to Plattner, to “manganate of baryta.” This characteristic reaction in presence of lime is surely sufficient of itself to establish manganese as a valuable reagent, and it is evidently best applied in solution. This is simply made by pouring a few drops of concentrated hydric sulphate on a little of the pure brown binocide of manganese in a test tube, and boiling till the latter is dissolved. The solution is at first deep olive-green, but by addition of distilled water becomes a fine crimson color, which shortly acquires a brownish tinge. If put into common glass bottles a thick brown crust is formed on the sides, which falls to the bottom as a brown powder. This does not happen in good German glass bottles, and would appear therefore to be due to a manganic reaction under the actinic solar rays upon some component (alumina?) of the glass. At any rate, Mn. sulphate solution gives, when heated with alumina in presence of soda especially, a fine brown, and as silica is colorless under similar conditions, the former earth may thus be detected, though in very small proportion, in most silicates. The mineral *Cryolite* is an admirable illustration of this fact, affording when thus treated a rich chocolate-brown, from which it would appear that the soda test is not always sufficient for the detection of manganese. This solution has the advantage over that of cobalt of never becoming reduced in O.P. to a black protoxide, which has the effect of concealing other reactions. The following is a list of some of the chromatic reactions of Mn. solution :

Potash (pure)	.. .. .	A deep-toned blue-green.
Soda	.. .. .	„ green-blue.
„ with alumina	.. .. .	Brown.
Baryta	.. .. .	Yellowish-green.
Alumina (pure)	.. .. .	Drab-yellow.
„ with soda	.. .. .	Brown.
Magnesia	.. .. .	Salmon pink.
Silica	.. .. .	Remains white.

The solution should be heated after application, in O.P., which, however, should be directed only on one part of the fragment, when the characteristic color will be found on the *other* side. Berzelius tells us:† “Of all the substances which Gahn tried, cobalt was the only one which gave a useful

* *Vide* Calcic Borate.

† Page 42, note.

result." Gahn, however, appears to have experimented in this direction by candle-light; whereby, although he first obtained it, he lost the honour of discovering the beautiful alumina blue, which was thus reserved for Thénard. As the great object in applying all such solutions is to avoid *reduction*, they are better applied on an Al. spoon* than on charcoal, and Mn. solution has the curious effect, when thus heated, of plating the aluminum with a beautiful silvery coat, apparently of metallic manganese, which seems to increase its infusibility. Manganic sulphate affords also one of the most delicate known tests for hydric nitrate, as follows: "If a small crystal of it be placed in a porcelain capsule, covered with hydric phosphate, and heated to dryness, a colorless residue is obtained; but if the smallest quantity of nitric acid or a nitrate be present, it has a violet, crimson, or dark red color, according to the quantity of nitric acid." (Noad.)

MANGANICOBALT SOLUTION, in which the well-known property of manganic oxides to pass on additional oxygen, is utilized to prevent the reduction of the chromatic peroxide of cobalt to the black or greenish-grey ("gris verdâtre," H. Rosé) of the protoxide.

MAGNESIC SULPHATE, for disengaging phosphoric acid from minerals, &c., in $\text{H}\ddot{\text{B}}.$ † The crystallized salt is best, as it forms an appreciable quantity for a balance—a good qualification where reagents are used in mere specks. It is obtained cheap and pure from any druggist, and need not be kept in a stoppered bottle.

(114). PHOSPHORIC ACID, or HYDRIC PHOSPHATE (symbol, $\text{H}\ddot{\text{P}}.$).—The glacial acid is purest sold in sticks, something like those into which caustic potash is fused. To prepare this acid for use, a sufficient quantity of these sticks to fill it should be placed in a platinum capsule or saucer, over the jet of a table blowpipe worked by a foot treadle, and heated to redness, until the black carbonaceous particles which form are burned away, and the stage of thick blue smoke and a pleasant smell evolved has passed. The platinum cools much more rapidly than the fluid glass formed, from which, therefore, when this cracks away from the platinum on cooling, it is easily detached, and that should not be longer heated than above indicated, as the $\text{H}\ddot{\text{P}}$ is slowly volatilized, and loss occasioned. The cake or glass extracted from the platinum is now pounded in a Wedgwood mortar, previously cleaned with strong *aqua regia*, rubbed in it with the pestle, and well washed after with distilled water. This cake is very hard, and should not be crushed finer than a coarse powder, of which each particle is the size of a pin's head. The first I made was of a brownish-white color, from the incomplete combustion of the carbonaceous particles,

* Paragraph (93).

† Vide Paragraph (216, b, c).

but I have no doubt the chemists would turn it out as a white powder, as I afterwards did.

(a). Thus prepared, this admirable reagent can be kept (in a wide-mouthed stoppered bottle) in any climate, any length of time, without deliquescing; and although it smokes a little, there is nothing unpleasant or unwholesome in its use, but quite the contrary, as the smell is agreeable, and, even when tasted, the acid is quite harmless. It is used by simply taking up the required quantity (which a little practice soon reveals to the eye) on the red-hot ring of a platinum wire. There is little ebullition, as the superfluous water has been got rid of by the above-mentioned fusion. It is, however, evidently a mistake to call it, when thus fused into a bead or glass, "anhydride," as is done in most chemical works, for, that it contains hydrogen may be proved by fusing in it, under O.P., a small piece of pure zinc, when a strong smell of hydric phosphide is perceived. Fused on platinum wire *per se* it does not in the least attack that, but if combined with carbon (by adding powdered graphite to the bead, or fusing this previously on charcoal) it does attack, and, what seems strange for such a highly oxidized substance, it *reduces* platinum, first forming with it (apparently) a fusible carbo-phosphide of the metal, which, thus treated, fuses rapidly into a ball, which crystallizes, or at least did in one specimen now in my possession, in apparently regular hexagons over the surface. The pyrological addition of hydric arsenate also enables $\ddot{H}\ddot{P}$ to attack platinum, and the bead thus formed under O.P. is a brilliant topaz yellow, which I at first attributed to the reaction of arsenic acid, until suspecting the truth from the precipitation of a dark non-volatile oxide in H.P., I tried the former alone with $\ddot{H}\ddot{P}$ on charcoal, and got no yellow reaction.

(b). If not previously fused, $\ddot{H}\ddot{P}$ should be prepared on the platinum ring, taken up in pin's-head fragments at first, under P.P., in which it first boils, projecting sometimes hot drops of fluid which sting the skin. While this effervescence goes on, a red-orange pyrochrome is produced, which flickers up round the blue pyrocone. When this phenomenon ceases, a lurid pale green pyrochrome commences, accompanied by a thick blue smoke, which has a pleasant incense-like odor. It will be observed that the moment this second reaction commences, and not before, black particles resembling carbon are separated, which glow for a second in the intense heat, and then disappear. Bubbles (of CO_2) (?) are generated by the extinction of these black particles, which, as they burst, flicker up, orangizing the pyrocone, and the bead, which before this showed a tendency to drop off, becomes much more viscid, especially if the O.P. be directed on its lower extremity, which should invariably be done until this takes place. When all these bubbles have been expelled by O.P.,

the glass remains beautifully clear and translucent, but by no means so vitreous or refractive as the $\ddot{H}\ddot{B}$ glass, and is now ready for use. At this stage, and always after, the pyrochrome is red-orange, redder than that of soda, but in H.P. the lurid green pyrochrome reappears, with the red-orange tint bordering its extremities.

(c). A distinguished chemist assured me (after I had been using this reagent for three years) that it was "impossible" to fuse this substance into a bead before the blowpipe, on account of its volatility; and it was, in fact, impossible in his laboratory, where there were only Bunsen, or aërated gas burners, the artificial pyrocone produced from which volatilizes it very rapidly. The fact is, phosphoric acid is slightly volatile before the pyrogene until a base (or assay) is added to it, when the salt formed is extremely stable under O.P., and loses but little after long heating.

(d). This reagent is especially adapted for the examination of alloys, and the chromatic oxides of what are called "the metals proper." The resulting colours are, generally, similar to those afforded by microcosmic salt, only apparently more brilliant, and produced by a smaller trace of the oxide. A remarkable exception, however, is cobalt protoxide, the smallest speck of which produces a pink (not a blue) coloration, although the glass is blue while hot. When the protoxide is added to the extent of 5 per cent. the glass is chromatically saturated, for the color cannot be heightened by further addition: it is then a perfect violet, and the most beautiful of all the colored glasses: the addition of 17 per cent. of an alkali turns it blue. It is evident from this and other facts, that the assumption of "free" acid in microcosmic salt (which is asserted to be its most valuable qualification), by writers on the blowpipe since Bergman,* who first stated it as a fact, is erroneous, and that the truth is, that microcosmic salt acts at most as a neutral, but most probably, for its basic is less volatile than its acid component, as an *alkaline* flux. On this account, perhaps, $\ddot{H}\ddot{B}$ is far more sensitive to oxidizing and reducing influences than the former, and in many cases, as with copper, antimony, bismuth, &c., does not require the addition of *tin* to produce the precipitation in H.P. of a suboxide, or, on the other hand, the addition of nitre to develop the color of a manganese oxide.

(e). A list of the colors afforded to this reagent by some of the chromatic oxides will be found under the head of "Systematic Qualitative Analysis," Part I.; but it should be mentioned here that, in order to detect small traces of these, the true color of the pure oxide or of the combined oxides in $\ddot{H}\ddot{B}$ being ascertained from the index or list, the slightly

* *Vide* Paragraph (108).

colored glass is held over an equal shade of the complementary color (Plate II.), and the color of the rays which have thus passed through the glass, compared with the corresponding shade of its complementary combination (Plate III). Thus, suppose a $\ddot{H}\ddot{P}$ glass tinged by cobalt = Hd (Plate II.), held over its complementary Ded , on the same plate, it ought to correspond with the shade "cherry" d (Plate III). The immense advantage of the acid $\ddot{H}\ddot{P}$ over the salt (microcosmic) and borax as a chromatic detective and also estimator, is well illustrated by the color it gives with cobalt oxide, which affords with the two latter reagents a primary color (blue), the shades of which do not vary, whereas with violet the weakest shade is merely pink, which acquires a blue tint as it gets stronger, i.e. acquires more of the oxide. Under O.P., $\ddot{H}\ddot{P}$ is the most powerful of all acids, as small pieces of gold leaf are oxidized and dissolved in it quite rapidly, giving the glass held in a certain position the beautiful blue-violet tint known as "purple of Cassius."

(f). Operations in this pyrological acid have the advantage over those in water acid solutions, of allowing the peroxidation or precipitation of some assays, without the addition of other reagents, but merely by altering the position of the bead of the pyrocone, while all oxides may be precipitated as in the "wet way" if desired, by simply dissolving the crushed glass in boiling water, and precipitating with some common and portable salt as ferrous sulphate: gold and silver oxides are thus obtained as a curious chalk-white powder, extremely deliquescent, which I have not had leisure to examine further, except as regards the former.*

(g). This pyracid cannot indeed be diluted as "mineral" acids are in chemical operations, but the same, and even a greater result is obtained by holding the glass in a long P.P. when it attacks and dissolves some oxides in this amount of heat, but not others. Many oxides, as, e.g. of iron, can be separated from that of tin, which belongs to the latter class, in this way. It only remains here to remark the extraordinary and most interesting behaviour of the purest metals† in this reagent under a cautious P.P. They are not only apparently decomposable into other substances, but invariably into the same substances: (a) a black mass; (b) a brick-red oxide; and (c) a gas. In the case of the more difficultly oxidized metals, as platinum, gold, and, in some degree, copper, (a) is replaced by a vitreous syrupy matter, which exudes from the metal and spreads

* *Vide* Gold.

† The metals tried by me were as follows: *Platinum*, *aluminum*, and *magnesium*, prepared by Messrs. Johnson and Matthey, of Hatton Garden; *gold leaf* from India; *silver* reduced *per se* on charcoal from the nitrate; *cadmium*, *copper*, and *zinc*, from the R. A. Institution laboratory; *lead* deposited on zinc from the acetate, from Freiberg, as "probir blei;" *tin*, a Freiberg reagent; *potassium* and *sodium*, from Messrs. Townson and Mercer, London.

through the glass like the appearance given by a piece of sugar slowly dissolving in little water. Tin and mercury are the only exceptions I know of: the first gives off the vitreous matter, and two or three white, semitransparent, organic looking crystals, like some mollusca, shaped like rolls of fine paper or shells, and these seemed to have hairs on them. These filamentary bodies increased by further treatment with P.P. Mercury seemed wholly made up of vitreous matter. I should of course have attributed these phenomena to some impurity in the metal, had they not been in all cases, with the exceptions above mentioned, so exactly alike.

(h). In order to observe these properly, a small piece of the metal must be taken on the bottom of the hot $\ddot{H}\ddot{B}$ glass, which, after that, must not be inverted, or the metal will most likely alloy with the platinum wire; a careful P.P. must then be directed, not on the metal, but on the platinum ring at top of the glass, so as to just heat the latter to redness, in which state it attacks most metals. The glass is now carefully withdrawn from the fire, smelled for S., &c., and the assay examined through a powerful lens. Some metals under this treatment will take fire, and burn with a brilliant pyrochrome, not generally the same as they afford when ignited *per se*; most will have partly fused to a ball, but all will have also afforded the appearances above mentioned. The slightest momentary changes are thus minutely observable in substances contained in the $\ddot{H}\ddot{B}$ glass, like flies in amber.

(115). POTASSIC CARBONATE is used (a) for gradually fluxing $\ddot{H}\ddot{B}$ glasses or beads containing phosphatic essays,* and thus liberating the phosphoric acid from its base for detection in $\ddot{H}\ddot{B}$, or sometimes for separating magnesia from lime, where those oxides are combined; (β) for enabling $\ddot{H}\ddot{B}$ to dissolve chromatic fragments or balls, and thus obtain a distinctive indication by the color of the whole glass or bead, in which operation the green pyrochrome is observed to be first heightened; and, when the flux thus made has gained an alkaline character, to be changed to violet; and (γ) for inducing characteristic crystallization in many glasses or beds, as e.g. in a sulphomagneboric one.†

POTASSIC TUNGSTIBORATE.—A flux for detecting phosphoric acid, and distinguishing between that and sulphuric acid.‡

PYROPHOSPHATE OF SODIUM.—The remarks under the head of "Borax" are applicable also to *microcosmic salt* (the curious derivation of which name appears to be *Μικρος* little, and *Κοσμος* world; because man was so called as representing the world in miniature, and this salt was originally made only from human urine), which may be kept to detect *silica*, but $\ddot{H}\ddot{B}$ answers that purpose better, and calcic $\ddot{H}\ddot{B}$ better still.§ M. salt has the further disadvantages of

* Paragraph (216, a). † Paragraph (129, m). ‡ *Vide* Tungstic Acid. § Paragraph (218, k).

having a nasty urinous smell when fused, and of being very deliquescent. It can always, however, be made if desired from $\ddot{\text{H}}\ddot{\text{P}}$ in the course of these analyses, by fusing in the proper proportion of soda.

(116). PYROPHOSPHIDE OF TIN.—Made by dissolving to saturation metallic tin in $\ddot{\text{H}}\ddot{\text{B}}$ on charcoal; the glass is then crushed and kept in a stoppered bottle. It is used for causing the appearance of suboxides of some metals dissolved in $\ddot{\text{H}}\ddot{\text{P}}$ or $\ddot{\text{H}}\ddot{\text{B}}$, and is preferable to tin, because it can be applied to a glass on the platinum wire, with which that would alloy.

(117). PYROPHOSPHIDE OF CARBON, seemingly analogous to carbonic disulphide, deserves a place here, if only for the unique property possessed by it of enabling a common O.P. to fuse platinum surrounded by it. $\ddot{\text{H}}\ddot{\text{P}}$ alone has little or no action on platinum even in the thinnest wire; but if condensed carbon, e.g. *graphite*, be applied under O.P. to the bead, that is observed to slowly dissolve the latter with evolution of many bubbles of gas, and to become at the same time brilliant and sparkling, when the wire is immediately attacked and broken through. A better, though perhaps not so pure way of forming this, the most powerful of all fluxes, is to fuse $\ddot{\text{H}}\ddot{\text{P}}$ on the purest obtainable charcoal in O.P., when—after intense ebullition, during which some charcoal is seen to be taken up in fine powder, and, covering the bead, to assume a semimetallic appearance—a beautifully transparent achromatic and retractive globule is formed, which then takes up no more charcoal: this of course must contain traces of lime, silica, &c.* Unfortunately this appearance does not last, as the flux is extraordinarily deliquescent, taking up water from the atmosphere even of a small corked bottle to such an extent, that it becomes after some weeks almost liquid. It, however, seems to dissolve silica to a very great extent, and the saturated silicious glass might not be deliquescent. It also seems to dissolve cut diamonds, but not the natural crystal.†

(α). POTASH CAUSTIC is used chiefly to detect *alumina*, which earth, when strongly heated with it, swells up like *Apophyllite* and then glows brightly.

(118). SODIC CARBONATE (symbol, Soda).—The bicarbonate should be fused in a platinum dish, after which, broken into fragments the size of a small pea, it keeps better in a stoppered bottle, and obtains reactions much quicker. It is chiefly used for detecting sulphur and sulphuric acid in compounds by forming a yellow or brown hepar, or effervescing (with the acid) with them; the fused mixture also invariably emits a bad smell of sodic sulphide. Soda is also useful for many purposes to be found under the separate heads, and a good supply of it should be kept. It is seldom sold impure by a respectable chemist, but should always be tested for S. or $\ddot{\text{S}}$ as follows: Fuse a small fragment in the P.P. of

* From the charcoal.

† *Vide* Paragraph (244).

a pyrological candle on aluminum plate; when quite cold add a drop of distilled water, when there should be no change of color or effervescence. To note the S. reactions, add now a small crystal of gypsum, and fuse again in P.P.: on addition of *water* there is strong effervescence, a smell, and a brown precipitate, which does not adhere to the plate. Now add to the fused mass a drop of *hydric sulphate*, and fuse again in H.P.; a brown ball forms (sodium hepar), which with a drop of water forms a *black* precipitate, with a disgusting smell. The student must be careful not to use *coal-gas*, as that always contains sulphur. It is necessary to use a candle for the purpose.

(a). Since the above paragraph was written, I have found that soda, prepared as above described, forms, when fused with the assay on aluminum plate, one of the two most delicate reagents for iron it is possible to conceive; detecting its oxide with the greatest certainty, not merely in presence of highly chromatic oxides, as those of cobalt, chromium, manganese, &c., but also in the most minute quantity. A fragment of this soda, fused in O.P., on platinum foil, runs into a pool or flat fluid mass, but on aluminum plate it will be found to congest into a ball, which is yellow and clear, hot, but becomes snow white and opaque on cooling. The reason of this remarkable difference seems that in the first case, the intense heat received at the point of incidence of the pyrocone, is preserved by the extremely limited heat-conductibility of platinum, within a very small area of surface round the point of the pyrocone, which area, therefore, is kept at nearly the same degree of heat; over this area the melted soda spreads as a fluid pool. Upon aluminum, on the contrary, heat is so rapidly conveyed away from the lower part of the soda, that that, following the usual procedure of fluids surrounded by and having an attraction to a proportionate heat, assumes a spherical form, except just at the bottom, where the heat is conveyed away. This fact is an immense and novel advantage to the operator, as will be seen by consulting the heads of reference to the use of this reagent under these conditions; for, on a platinum wire (the only other position where it will assume a spheroidal form) reduced metals, such as copper, will alloy with the platinum, an obstacle which cannot take place here. The importance of this reagent, thus used, depends chiefly on its power of reducing, under the same pyrocone, some contained oxides to the metallic state; others only to a lower, and, thus treated, colored oxide; others remaining apparently unchanged and colorless; while volatile oxides in the same combination are volatilized, and betray themselves on the aluminum at the back by the peculiarities of their sublimates. On this support soda is capable, like an acid flux, of allowing some substances dissolved in it to be oxidized by P.P., as, e. g. manganic binoxide, which is thus raised to manganic acid.

(b). Soda fused thus on aluminum forms a remarkable reagent for distinguishing between lime and magnesia—a test much required. Either of those earths combine* with some difficulty; the first easiest, with soda under O.P. to a semifluid ball, the earth apparently remaining on the side next the heat. If there is sulphur in the pyrocone, or if a speck of it be applied to the fused mass, the salmon color is not nearly so apparent; indeed it scarcely appears in the beads containing these earths when cold; but if those are left exposed to the air for an hour or so, the part where the earth has combined with the alkali becomes, in the case of magnesia, pale blue; in that of lime faint purple: paler and fainter in direct proportion to the causticity of the earth when combined.

(c). But the most remarkable fact is that magnesian soda retains a smooth surface over its bead, or showing only the usual hexagonal crystalline planes of soda cooled from fusion; while the calcic sodaline bead is covered on cooling with the most curious, raised, round crystals, like those rough sweets the confectioners sell. If iron is present the usual yellow-green spots of protoxide appear. I leave the solution of this phenomenon to those chemists who pretend to be able to supply an algebraical cause for every natural effect. All I assert here is that the reaction forms a most valuable method of distinguishing between lime and magnesia; but if a *natural* inference may be drawn, it certainly seems to be this, that lime thus fused, forms (however it may shock the chemists to say so) a chemical compound with soda, which crystallizes in the above-mentioned forms. But if that be so, the proportion of lime thus combining is very small, the greater part being left as an undissolved mass, having the fluid soda-lime in these crystals on its surface only. Baryta, which seems to combine in much greater proportion with soda, forms on the surface of the bead very large crystalline planes of a quite different character from those of soda.

SILICA, *in fragments*.—The purest and most soluble in \ddot{H} I have ever had is Indian (or Chinese) *tabasheer*, the silicious secretion in the joints of the bamboo. It is in soft, bluish-white opaque fragments, which when crushed afford a very beautiful azure blue powder. It contains nothing but water, hygrometric and constitutional, and is much more manageable as a reagent than even the purest rock crystal. It is sometimes used with soda in order to detect combined hydric sulphate, but does not seem necessary. I use it to separate lime from some of its compounds in \ddot{H} .† Plattner made a flux of it with soda and borax for the purpose of separating tin (combined with iron oxide) from copper, but I have not tried this.

(119). SULPHUR (symbol, S.) has the peculiar effect when ignited with

* I have used the word "combine" after careful consideration of the facts here detailed.

† *Vide* Lime.

water on a platinum tray, of causing or facilitating volatile deposits or sublimates on polished iron from some substances ignited with them. It is also very useful, and indeed, indispensable for detecting *nitrogen* in a different way; often in substances not supposed to contain it, as, e. g. some *Dolomites*. The assay is ground between agates to a paste with S. and a drop of water; placed, as in Fig. 55, on the platinum tray, and ignited: the hot steel leg of the forceps is then plunged into cold water, and comes out quite *black*. Sulphur alone, or S., and any mineral not containing nitrogen, may be thus tried, and the forceps leg will *not* change color. Gunpowder affords a good illustration of this reaction, as it contains both ingredients. It will "frizzle" a little at first, however watered, but that does no harm. The explanation of the phenomenon seems, that the *sulphurous* acid formed by ignition is converted into *sulphuric* acid, which, under this heat, sublimates as "anhydride," and is thus attracted and deposited on the steel, to be again converted into hydric sulphate, by plunging in water; when, of course, the iron is attacked by it, and the combined carbon of the steel laid bare. I was led to this experiment by the difficulty of detecting inorganic nitrogenous compounds (of which I was convinced many had remained unnoticed)* pyrologically. I first obtained nitrogenous reactions by repeatedly dipping a red-hot H^{P} bead in concentrated hydric nitrate, or in a strong solution of ammonia, and treating in a *good* H.P., always obtainable at the elevation (7500 feet) I was working in India. I thus got peculiar and very distinctive reactions,† but they were destroyed by the presence of iron and other substances. It then struck me that nitric acid, in some shape or other, is always used with steam, in the commercial manufacture of sulphuric acid, and, as I was then (1871) experimenting with various sublimates by heating through platinum foil, I tried watered gunpowder in this way, and being disappointed in any effect on the steel-legged forceps, plunged those into water, when they came out black, and rusted on drying. It is not easy to account for the conversion of free nitrogen existing in such substances as *stinkstone*, most *peats*, &c., into N_2O_5 (which, of course, must take place), in this way; but I presume that is effected, in the first place, by means of the sulphurous anhydride formed.

(a). Sulphur also forms an excellent detective for iron in chromatic oxides, as that of cobalt.‡ Also as a means of distinguishing between lime and magnesia.§ Pure crystallized sulphur should be used in pin's-head fragments. The hepar it forms when fused with soda has a delicate and beautiful salmon color, pale in proportion to the paucity of sulphur present, though this can be easily thus recognized in a human hair.

TUNGSTIC ACID, sold as a yellow powder, is indispensable for a rapid and

* *Vide* Nitrogen. † *Vide* Nitrogen. ‡ Paragraph (259, a). § Paragraph (118, b).

striking way of detecting phosphoric acid in combinations.* Its purity is tested by fusing some proof lead, covered above and below, with its paste, in a keyhole mortar on aluminum plate, and treating the sublimate in $\text{H}\ddot{\text{B}}$ under O.P., when any insoluble fragments indicate binoxide of tin. Five per cent. of it should color a 50-mgr. $\text{H}\ddot{\text{P}}$ bead = (G) after H.P.; or the flux can be kept ready for use.†

WATER, DISTILLED, is used for separating (by boiling) metallic pyroxides; for extracting sphèresphères, both from $\text{H}\ddot{\text{B}}$ and other purposes. As so little is required for pyrological purposes, the following process will supply a sufficiency of distilled water for a day's experiments: (1) Fill half full a clean common saucepan with as pure water as is obtainable—rain-water is best. (2) Have a small bucket or dish of *cold* water near; place the saucepan on a fire, and float the lid in the dish of cold water. (3) When the water in the saucepan begins to boil, close it with the lid, wiping off the cooling water in doing so; the inner edges will retain the condensed steam. (4) Remove the lid in a few seconds; pour off the distilled water; cool the lid as before, and repeat the process.

PYROQUALITATIVE ANALYSIS.

(120). GENERAL RULES.—Under this head, Berzelius‡ has forty-three and Plattner no less than eighty-nine closely printed (in German) pages. It would seem, however, that *general* rules for the investigation of inorganic substances by tests so rapid, and yet, if rightly judged, so crucial, as those afforded by the scientific application to them of fire, should be short and simple enough to be carried in the head. The details of such a work as analysis, far from being “general,” should be so *particularly* stated, that an error ought to be on the side of repetition rather than of vagueness. The inevitable consequence of such an arrangement as that adopted by the above celebrated authors is, that much valuable information has to be hunted out of these “general rules,” which ought to be *expressly* discovered under its proper head. There are, moreover, a few really “general” rules, which the student should retain, if possible, in his memory, as the following:

(α). Never attempt to learn, in the first place, reactions of particular substances, whether *per se* or with fluxes, by means of *minerals*, however pure these may be supposed to be; but only through the chemically *pure* oxides and metals, procured from a chemist whose name is in itself a guarantee of their

* Paragraph (216, A).

† *Vide* Potassic Tungstiborate.

‡ Am. trans.

purity.* A complete course of analysis with the latter should be gone through by the student before he attempts to touch the former, which *in no case* are to be essayed *as minerals*,† but only as particular combinations of certain oxides with each other, with silica, with water, &c. Such a course *must* be made by anyone who wishes to obtain a competent knowledge of this art, and he ought, moreover, to *personally* test the statements he finds in books (this one included).

(β). Do not throw away (as I regret now, I have so often done) the *results* of successful experiments, in the shape of colored beads, &c., or, what is even worse, keep them *unlabelled*. They should be kept, each specimen in one of the penny German bottles above mentioned, having its cork labelled with the symbol of what it is. They are then invaluable as a means of *comparison*; and this practice, moreover, teaches the student to be more methodical and careful in making his experiments. Educate the left hand: that is, practise it in doing things you are accustomed to do only with your right. Always add a drop or two of distilled water in grinding substances between agates to powder: if required dry, it can easily be dried by holding over it, or mixing it with, a red-hot platinum spatula for a few seconds, but watery powder taken up on a HB bead adheres in finer particles than any other. In writing descriptions, always use the *shortest* word which expresses properly your meaning. Avoid italics, except where absolutely necessary for the meaning.

(γ). Never begin the examination of a mineral or substance in the wrong way.‡ If you do, hours of valuable time will most probably be wasted. Never work with *cold* hands, through which you are very likely to drop and lose an essay or assay which you have been hours in obtaining. See that your platinum wires and all implements are *clean*, or you will probably be led into serious error. Examine your reagents, and even the gas with which you work, previous to use; not every time, of course, but once for all. Begin the morning with one (or more, according to the difficulty or ease of the examination) object in view; stick to that or those, and do not fly from one thing to another, or, on the other hand, remain so long engaged in one pursuit that you feel yourself getting

* I can confidently state the name of Messrs. Griffin and Sons, Garrick Street, Covent Garden, to be such (in England).

† A remarkable illustration of the danger of prostituting pyrological analysis to the purpose of obtaining *mineral* reactions is given by the generally careful and exact DANA. (*Vide* his splendid volume on 'Mineralogy,' p. 680.) In the description of the pyrological reactions of *Calcite*, he says that mineral "with soda on platinum foil fuses to a clear mass;" and he further says (p. 684), that *Dolomite* is distinguished from that "by not giving a clear mass when fused with soda on platinum foil." Now one of the very first notes the student is required to make is, that *lime* is *nearly insoluble in soda*, and would require a very large amount of some fixed *acid* to cause these bases to combine to anything like "a clear mass" under O.P.

‡ *Vide* Systematic Analysis: æsthetical examination.

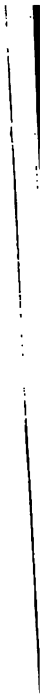
disgusted and tired, when you may be sure that your work will not be worth the time expended on it.

(δ). When a novelty occurs in the course of experiment, or any phenomenon in your results which may cause your conclusions to differ from those of former operators, repeat the experiment three times, and record the *mean* of the results, without allowing that to be influenced or modified by the statements of any writer, however celebrated. If your observation is, as it ought thus to be, correct, as well as new, it must evidently be valuable as an acquirement to science; but a new observation *apud* Berzelius or Plattner, &c., will be treated as a mere *difference* from *their* opinions, which, you may depend upon it, will remain unshaken by any assertion of yours. *A propos* of this remark, be extremely careful never to state or write even the smallest contribution of other writers to science *without acknowledgment*.

(ε). Never work without making notes (except, of course, if you have to try anything on the spot where it is found), and write these in an *alphabetical* notebook with, say, four or six leaves to each letter, as concisely as is compatible with intelligibility, adopting symbols and contractions wherever you can. It is better to drop the pyrogene, in order to take up the pen or pencil, than to write the whole after you have finished operations from memory; and never insert superfluous narrative, as, "tried so and so"; "thought this, so did that," &c. These sentences may be amusing to read, but writing them is a waste of time, and they are extremely confusing afterwards in referring for information or guidance to your notes.

(ξ). Keep your reagents in small fragments, *not* in *powder*. When a very small fragment or powder (which generally accompanies fragments) is wanted, shake the bottle upside down, when, on reversing it and taking out the cork, the powder will be found at the top, and can then be shaken out on the agate slab. You *cannot* use too small a fragment at one time for flux testing, especially in boric acid; more can always be added, if necessary, and an essay is, in nine cases out of ten, spoiled by taking up too much powder at once on the bead or glass.

(121). COLOR.—The analysis of inorganic substances—whether effected by means of fire, with ponderable results; of fire through the different refrangibility of separated rays of light; or by the precipitation of oxides or salts from their solution, as in "the wet way"—is in great measure effected by the operator's discrimination of *color*. Spectrum analysis, indeed, enables us apparently to avoid this discrimination in detail, by exhibiting a frame, as it were, on which (there is sufficient evidence collected from experiment to lead us to suppose) every possible colored ray of light has its particular and assigned position, so that it is this predetermined *position*, whether it is vacant



or black through absorption, or chromatically indicated, to which the operator refers, without the absolute necessity of estimating the shade of color to which it belongs; but, as if in revenge for the ingenious torture to which Newton's simple experiment has thus been put, so *many* positions or "lines" are already evolved from burning substances, and these lines are, in most cases, so *fine* that the *very* delicacy of this mode of analysis embarrasses the investigator to an extent—the extent of the greatest possible dispersion—which seriously threatens its utility in many cases. Iron alone, for instance, giving by combustion no less than 460 lines in the different chromatic spaces of the spectrum. But even supposing the spectrum method of analysis twice as practically useful as it is at present in the determination of terrestrial combined inorganic substances, the comparatively enormous expense of the complete apparatus required for burning and observing; the necessity of employing violent and unportable acids in many cases, and the infinitesimal nature of the results obtained, render this beautiful, but luxurious, and comparatively unpractical, mode of analysis almost beyond the scope of this treatise.*

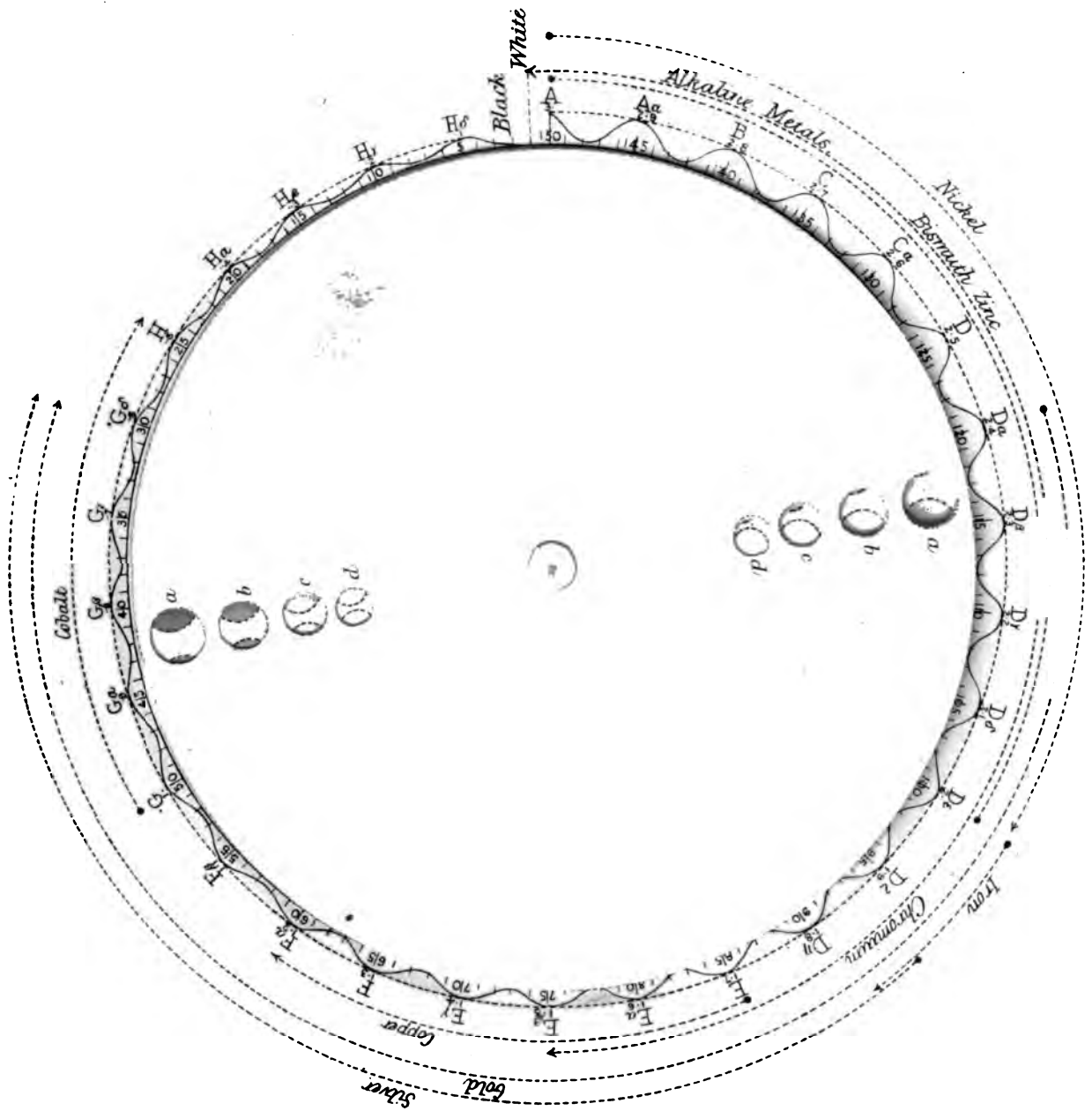
In the ordinary operations of chemical analysis, as a short examination of any work on the subject will convince us, little could be ascertained without the discrimination of color, whether of solutions or precipitates, and it may in consequence be fearlessly asserted that a blind chemist is an impossibility. Dalton, indeed, is said to have been what is called "color blind"; but although his beautiful theory is the mainstay of modern chemistry, he was not himself a practical chemist.

(122). Color is decomposed light. As there are three pure or "primary" colors, so white or normal light (the result of a perfect combination of those three) may be apparently decomposed in three ways. (a) By the *refraction* of its component or colored rays, as in a prism. (b) By the *transmission* through partly-transparent media, as glass having chromatic metallic oxides dissolved in it, of one or two of these rays, the passages of the other or others being stopped, whereby a colored or decomposed light is thrown upon objects, between which and normal or undecomposed light the semitransparent medium has been interposed; transparency being strictly the property possessed by a substance, with parallel surfaces not too close together, of transmitting white, or normal light, unaltered, so that the objects shall be seen through it exactly as they are. For instance, a telescope having colored lenses would transmit a *deficient* impression of objects. These lenses then could not be termed quite transparent. (c) Through the *reflection*, by most natural and artificial substances, of only one or two of the three rays composing

* Since this was written I have devised a *spectrum lorgnette*—Paragraph (104)—by which this method can be more cheaply applied.

PRISMATIC COMBINATIONS.

Plate II.



the normal white light thrown upon them from the sun ; the other or others being "absorbed," that is, not thrown back from or passed through the object, whose reflected light is therefore not normal or white, but decomposed or colored.

Thus the petal of a scarlet geranium, a "crowfoot," or "butter cup," and a "forget-me-not," decompose normal daylight as effectually, though not so completely, as a prism, for they only reflect the three primary colors, red, yellow, and blue, whereas that affords to the retina not merely these, but also twenty-seven of their combinations, progressing not harshly, but gradually blending one into another, and apparently also in a circular series; for, at whichever color an observer begins to observe, and whether he proceed from right to left, or *vice versâ*, he finds his eye led back, almost insensibly by gradual tints to the same color again. Thus, if we commence at A "in the red" of the solar spectrum, and look towards the right, we find, after passing G "in the blue," a tinge of red beginning again in the shape of "violetish-blue," until it "warms" the "cold" blue into a violet, and brightens that at its ultimate edge into "pink," the tint called "indigo" being apparently due to loss of light, or, in other words, to the introduction of black.

(123). The spectrum of a ray of solar light as presented to us by the prisms in common use, may, therefore, be apparently considered the oblong representation of a really round object, as a map of the world on "Mercator's projection" is. Plate II. is an attempt to represent the prismatic colors circularly arranged in the following tintual gradations from the red towards the right, primaries being distinguished by large capitals; primary complements by small capitals. A,* RED; Aa, Orangish Red; B, Orange Red; C, Red Orange; Ca, Reddish Orange; D, ORANGE. This completes the first sequence of five tints. Da, Yellowish Orange; Dβ, Yellow Orange; Dγ, Orange Yellow; Dδ, Orangish Yellow; Dε, YELLOW—the second sequence. Dζ, Greenish Yellow; Dη, Green Yellow; E, Yellow Green; Ea, Yellowish Green; Eβ, GREEN—the third sequence. Eγ, Bluish Green; F, Blue Green; Fa, Green Blue; Fβ, Greenish Blue; G, BLUE—the fourth sequence. Ga, Violetish Blue; Gβ, Violet Blue; Gγ, Blue Violet; Gδ, Bluish Violet; H, VIOLET—the fifth sequence. Ha, Reddish Violet; Hβ, Red Violet; Hγ, Violet Red; Hδ, Violetish Red—the sixth and last sequence.†

* The application of these letters is evidently absurdly unmethodical, but it is better to retain Fraunhofer's nomenclature, which is still used in describing spectra.

† The idea of a circular arrangement of prismatic colors is very old. Chevreul says (p. 56, Martel's translation): "Several graphic constructions have been proposed under the denomination of color circles, chromatometers," &c. Chevreul's own "chromatic circle of hues" (*sic*) is something like Plate II., but he has sixty instead of thirty radial divisions, like colored spokes of a wheel, only twelve of which are named.

(124). There is no necessity in a practical work of this kind to introduce the abstruse subject of mathematical optics, but the now universally accepted theory, first rationally propounded by the Dutch philosopher Huygens—in opposition to the opinion of Newton, who could not see “how light can turn a corner”—that “the propagation of waves, whether of sound or light, is a propagation of energy,” and that “each small portion of the medium experiences successive changes of state, involving changes in the forces which it exerts upon neighbouring portions, and thus a disturbance existing at any one part is propagated onwards,”* may properly be here referred to. On this theory, color is described as the property possessed by some bodies to “reflect some rays in larger proportion than others, and they are therefore colored, their color being that which arises from the mixture of the rays which they reflect. A body reflecting no light would be perfectly black; practically, white, grey, and black differ only in brightness. . . . A transparent body, seen by transmitted light, is colored, if it is more transparent to some rays than to others,† its color being that which results from mixing the transmitted rays. . . . Some transparent substances appear of very different colors according to their thickness. A solution of chloride of chromium, for example, appears green when a thin layer of it is examined, while a greater thickness of it presents the appearance of reddish-brown. In such cases, different kinds of rays successively disappear by selective absorption, and the transmitted light, being always the sum of the rays which remain unabsorbed, is accordingly of different composition, according to the thickness. When two pieces of colored glass are placed one behind the other, the light which passes through both has undergone a double process of selective absorption, and, therefore, consists mainly of those rays which are abundantly transmitted by both glasses; or, to speak broadly, the color which we see in looking through the combination is not the sum of the colors of the two glasses, but their common part. Accordingly, if we combine a piece of glass colored red with oxide of copper, and transmitting light which consists almost entirely of red rays, with a blue or violet glass of about the same depth of tint, and transmitting hardly any red, the combination will be almost black. The light transmitted through two glasses of different color, and of the same depth of tint, is always less than would be transmitted by a double thickness of either; and the color of the transmitted light is, in most cases, a color which occupies in the spectrum an intermediate place between the two given colors. Thus, if the two glasses are

* ‘Deschanel’s Optics,’ Everett’s translation, pp. 865, 1000.

† This sentence is evidently illogical, involving the confusion of “transparency,” meaning a want of transparency. See Paragraph (121).

yellow and blue, the transmitted light will, in most cases, be green, since most natural yellows and blues, when analyzed by a prism, show a large quantity of green in their composition. Similar effects are obtained by mixing colored liquids."

(125). The weak point in the armour of this beautiful theory is evidently indicated in the words "*selective absorption*." Why is a laurel leaf green, and a red-geranium petal red? Because the first *selects* green rays, or rays composing green, for reflection, and *elects* to "absorb," that is, in some unexplained way, to annihilate all others; while the last elects to reflect red rays, and to absorb the rest. This reply seems to me to beg the whole question, and to leave the "anxious inquirer" just where he was before. They choose to be green and choose to be red, and that is all we at present know. An authority on the subject, however, thus writes to me privately: "As to elective absorption, the details of it have yet to be made out, but this much may be looked on as well ascertained: that absorption depends on the vibrations being spent in producing molecular motions within the vibrating body, and that the elective character of absorption has to do with a synchronism between the pervaded time of the incident vibrations, and that of certain motions capable of being excited among the molecules of the body." This explanation, although containing a closer investigation of the mystery than Deschanel's description does, still seems to leave the question in an eleemosynary condition by the use of such words as "spent" and "capable." Why are certain vibrations spent, and not others? Why certain motions capable of being excited, and not others? We must therefore apparently, for the present, rest satisfied on this point with some such "explanation" as that given by Johnson to Boswell, "Don't ask me *why*, sir: it is sufficient for you that it is so."

The difference between the vibrations of sound in air and those of light in "ether" is thus described by Deschanel*: "Light, like sound, is believed to consist in vibration; but it does not, like sound, require the presence of air or other gross matter to enable its vibrations to be propagated from the source to the percipient. It seems necessary to assume the existence of a medium far more subtle than ordinary matter. . . . This hypothetical medium is called *æther*. . . . Its elastic properties are rather those of a solid, and its waves are analogous to the pulses which travel along the wires of a piano, rather than to the waves of extension and compression by which sound is propagated through air. *Luminous vibrations are transverse, whilst those of sound are longitudinal*. . . . All kinds of luminous waves (like all kinds of sonorous waves) have the same velocity in the same medium; but this velocity is many

* Page 865.

hundreds of thousands of times greater for light than for sound, and the wavelengths of light are at the same time very much shorter than those of sound."

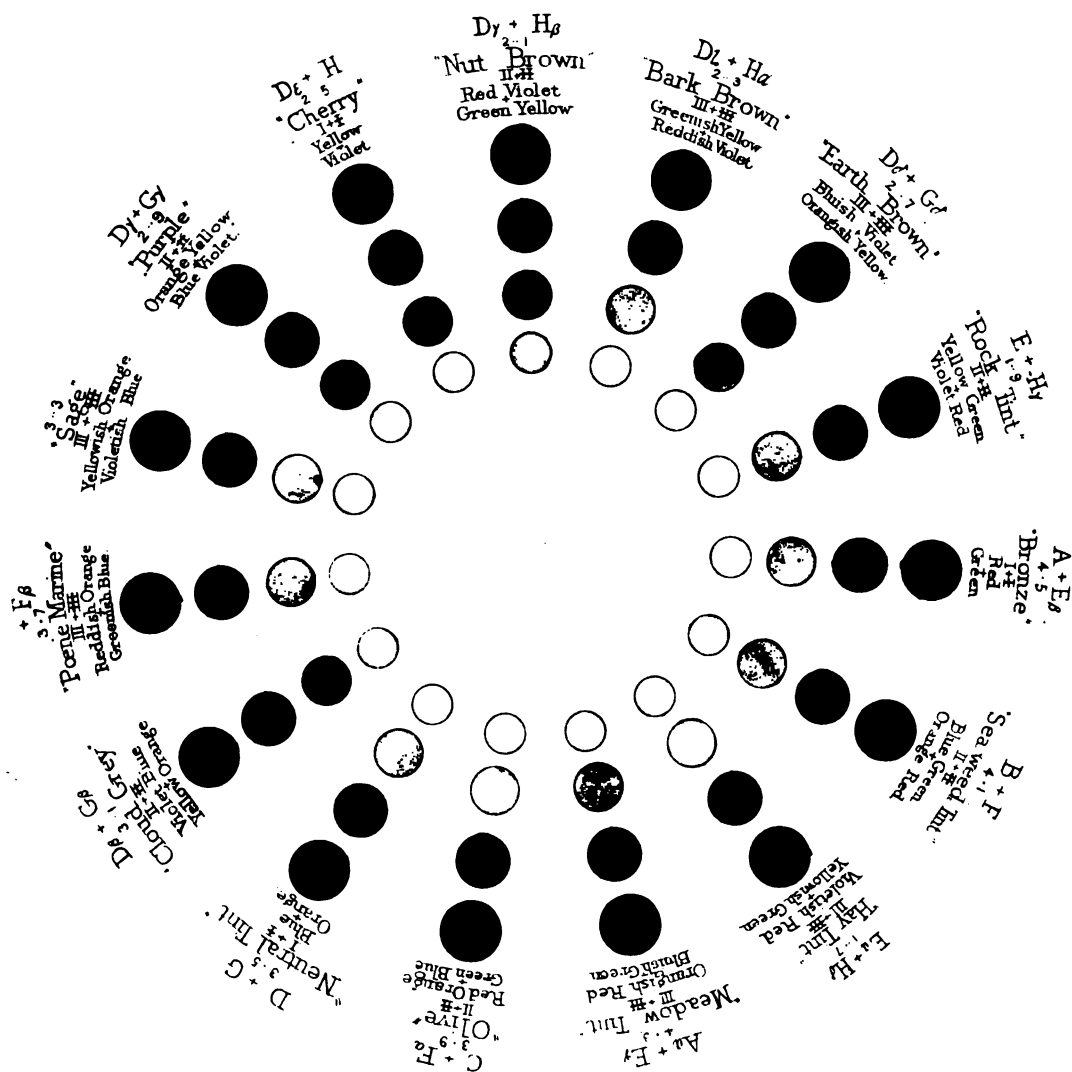
(126). It thus happens that mathematicians do not admit (or at least take no note of) "amplitude" of waves of light as of sound; that is, their breadth or height, but only of their length; that is, from crest to crest; and impossible as it may seem, this has actually been *mechanically* measured by means of what is technically termed a "grating," which is a piece of glass with infinitesimally fine lines ruled over it.

On an hypothesis, however, of amplitude in luminous vibrations, the phenomena of "selection" and "absorption" of particular colored rays by different substances might be accounted for; because substances whose particles can be agitated by vibrations of any kind, however minute, must have spaces between those, or *pores*; and if we can imagine vibrations having different amplitudes, it would not be difficult to assume pores of a corresponding magnitude; into some of which, for instance, waves of comparatively greater amplitude, as red, could not pass, while violet vibrations would be freely admitted. On a similar hypothesis would be accountable the curious phenomenon that chromatic beads or glasses are of a different color when hot to that they are when cold—a phenomenon I do not remember to have seen accounted for; because, if we conceive an expansion of such "light-pores" by heat, the rays of greater amplitude would pass into the hot body, and be gradually excluded as that cooled. This, of course, is a mere hypothesis, and one, too, not in accordance with the mathematical theories on the subject, but it seems to account for "selective absorption," and for the change of color in hot substances cooling. Thus, if we imagine the red waves at A (Plate II.) to possess the greatest amplitude, and that to proportionately diminish till we come to H δ , or violetish-red, we find the oxides of various metals dissolved in a bead, say of $\ddot{H}\ddot{P}$, to be colored at hottest where the black dot or ball is shown in the dotted lines; to pass through the colors covered by those in the direction of the arrow, and to end at that when cold. Thus, oxide of gold commences at Da, or yellowish-orange, when hottest, and passes through all the intermediate colours to G δ , or bluish-violet, covering a greater chromatic range, as its metal may be supposed to be when cold less porous or more dense than any other except platinum. It is a curious fact with regard to this hypothesis, that oxide of bismuth—a metal which *expands in cooling*—proceeds in *the other chromatic direction in cooling*, viz. from De, or yellow, to white.

(127). The analytical use of Plates II. and III. is very simple. A glass of phosphoric acid is slightly tinged (for instance) with a minute speck of *cobalt* oxide dissolved in it. To compare the faint pink bead thus produced *directly* with the colored rings *c* or *d* of H or violet on Plate II., could scarcely ensure

COMPLEMENTARY COMBINATIONS.

Plate



EXPLANATION OF PLATE III.

THESE combinations seem at first sight to be merely fortuitously arranged browns and olives, &c.; but there is an evident natural order springing from the mixture in this manner of pure pigments, if we consider, as we certainly ought, the combination of two primaries (as violet) to be still a primary color, but in the second place, or a resultant-primary, noted by a dash through the roman numeral I. Thus "cherry" (which should have been perpendicularly situated in this plate) is the combination of a primary (yellow) with a resultant-primary (violet). "Nut brown," the next series to the right, is the combination of a *secondary* (or the pigmental addition in excess of a primary to a resultant-primary, as green-yellow) with a resultant-secondary (or the pigmental addition in excess of a resultant-primary to a primary, as red *violet*). It is indicated by placing the plus sign between the roman numerals II., and II. with a dash. "Bark brown," the third series, is the combination of a *tertiary* (or the pigmental *tinging* of a primary with a resultant-primary, as greenish-yellow) with a resultant-tertiary (or the pigmental tinging of a resultant-primary with a primary, as reddish-violet), indicated by the plus sign between the roman III., and III. with a dash. Evidently we cannot go beyond this, and there can therefore be no quaternaries, so that "earth brown," the fourth series, is merely placed to the right of "bark brown."

correct results, for the operator could not be certain, either that the color shown in one or other of those rings represents the exact shade of violet afforded by that amount of cobalt oxide; or that the latter really bestows on this glass violet of any shade, and not G δ or bluish-violet, or reddish-violet (Ha). If, however, by turning the paper cover with its diameter of holes, until one radius of those is over the line of violet rings, he finds the rings of the complementary color under the other radius, and holds the faint pink bead *over* a similar shade or ring of that, and examines the light which is thus transmitted *through* the glass with a lens, he will find it to coincide exactly with one of the shades of 2·5, Plate III., or “cherry”; proving that the selection of *violet* as the real tint of cobalt oxide dissolved in phosphoric acid is right, and also proving, if necessary, that the oxide he has in this glass must be due to *cobalt*. Before I devised this plan of examining the colors of beads methodically—identifying them in the loose way we so often see, even in scientific works, as “a fine green,” “a deep blue,” &c.—I imagined this very tint to be “*red-violet*,” and erroneously called it so in a late paper of mine;* but it will be at once seen by Plate III., 2·1, that the rays transmitted through red-violet by its complementary green-yellow, have a perfectly different and easily distinguishable tint from “cherry,” i. e. that which I have here called “nut-brown.” It is evident that every possible tint may in the same way be identified by rules derived strictly from Nature herself, and which I have, so far as I have been able to express them by pigments, ventured to distinguish by names also derived from Nature, in preference to those individualistic epithets which we find in use among artists, as, e. g. “Payne’s grey,” “Saunders’ blue,”† &c., which must differ with every different nation.

It is impossible at present to publish a chromatic expression of the tints thus derivable from the “law” of what Chevreul calls “simultaneous contrast of colors,” but which seems nothing more than “*successive* contrast” of the complementary color, more rapidly contrasted; so I append here an arithmetical expression of them:

	Tints.
Prismatic Combinations (Plate II.)	30
Complementary „ (Plate III.)	15
Normal „ (Plate IV.)	7
Table of Compound Tints (Table I.)	450
„ Prismatic Tones (Table II.)	210
„ Complementary Tones (Table III.)	105
Total tints	817

* *Vide* ‘Proceedings,’ vol. xx., p. 457, of the Royal Society.

† “Saunders’ Blue,” however, is apparently portrayed by Nature herself, for it is said to be the precise tint at the tail—or rather, instead of the tail—of one of the baboons.

TABLE II.—OF PRISMATIC TONES.

	Red = 3	Orange Red = 2.9	Orange Red = 2.8	Red Orange = 2.7	Reddish Orange = 2.6	Orange = 2.5	Yellowish Orange = 2.4	Orange = 2.3	Yellow Orange = 2.2	Orange Yellow = 2.1	Yellow = 2	Greenish Yellow = 1.9	Green Yellow = 1.8	Yellow = 1.7	Yellowish Green = 1.6	Green = 1.5	Blueish Green = 1.4	Blue Green = 1.3	Green Blue = 1.2	Blue = 1.1	Blue = 1	Blue = .9	Violet Blue = .8	Violet = .7	Blueish Violet = .6	Violet = .5	Reddish Violet = .4	Red Violet = .3	Violet Red = .2	Violetish = .1
M Black. .5	3.5	3.4	3.3	3.2	3.1	3.0	2.9	2.8	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.0	0.9	0.8	0.7	0.6
A Grey Black. 3.75	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.1	5.0	4.9	4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.1	4.0	3.9	3.8
K Black Grey. 7	10	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1
Q Grey. 10.25	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3
Z White Grey. 13.5	16.5	16.4	16.3	16.2	16.1	16.0	15.9	15.8	15.7	15.6	15.5	15.4	15.3	15.2	15.1	15.0	14.9	14.8	14.7	14.6	14.5	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6
A Grey White. 16.75	19.7	19.6	19.5	19.4	19.3	19.2	19.1	19.0	18.9	18.8	18.7	18.6	18.5	18.4	18.3	18.2	18.1	18.0	17.9	17.8	17.7	17.6	17.5	17.4	17.3	17.2	17.1	17.0	16.9	16.8
I White. 20	23.0	22.9	22.8	22.7	22.6	22.5	22.4	22.3	22.2	22.1	22.0	21.9	21.8	21.7	21.6	21.5	21.4	21.3	21.2	21.1	21.0	20.9	20.8	20.7	20.6	20.5	20.4	20.3	20.2	20.1

TABLE III.—OF COMPLEMENTARY TONES.

	Cherry = 2.5	Nut Brown = 2.1	Dark Brown = 2.3	Earth Brown = 2.7	Rock Tint = 1.9	Bronze = 4.5	Sea-weed Tint = 4.1	Hay Tint = 1.7	Meadow Tint = 4.3	Olive = 3.9	Neutral Tint = 3.5	Cloud Grey = 3.1	Peach Marine = 3.7	Sage = 3.3	Purple = 2.9
M Black = .5	3.0	2.6	2.8	3.2	2.4	5.0	4.6	2.2	4.8	4.4	4.0	3.6	4.2	3.8	3.4
A Grey Black = 3.75	6.2	5.8	6.0	6.4	5.6	8.2	7.8	5.4	8.0	7.6	7.2	6.8	7.4	7.0	6.6
K Black Grey = 7.0	9.5	9.1	9.3	9.7	8.9	11.5	11.1	8.7	11.3	10.9	10.5	10.1	10.7	10.3	9.9
Q Grey = 10.25	12.7	12.3	12.5	12.9	12.1	14.7	14.3	11.9	14.5	14.1	13.7	13.3	13.9	13.5	13.1
Z White Grey = 13.5	16.0	15.6	15.8	16.2	15.4	18.0	17.6	15.2	17.8	17.4	17.0	16.6	17.2	16.8	16.4
A Grey White = 16.75	19.2	18.8	19.0	19.4	18.6	21.2	20.8	18.4	21.0	20.6	20.2	19.8	20.4	20.0	19.6
I White = 20.0	23.5	23.1	23.3	23.7	21.9	24.5	24.1	21.7	24.3	23.9	23.5	23.1	23.7	23.3	22.9

Examples of using the Tables.—A tint is required by the mixture of Violetish Blue with Earth Brown. In Table I. this is shown to be IV. 3.6 or IV. 2.7 + .9. Violetish Blue is required to be toned with Grey White. By Table II. we find this to be 17.0, or the required tone may be a mixture of Peach Marine with Grey White, which is (by Table III.) XIII. 20.4.

(128). I recommend the student who has sufficient time and patience, to try to produce these tints, or any number of them he can, with a paint-box of pure colors: he will then have an immense index of colors, with which to compare the phosphoric acid, or lime-borate, or soda-borate bead, colored by the fusion or solution in it of any mineral; and there are few, if any, minerals which, under certain treatment, will not afford, with one of the above fluxes, a chromatic bead. In India, in 1871, I dissolved the fine powder of a mineral which afforded only the reactions of silica, little by little, to saturation without opacity, in borax, and eventually, after a fortnight's labour, obtained a bead of a perfectly pure cerulean blue, so hard and tough that I failed to break it on a steel anvil with a hammer; and that this blue could not be due to a trace of cobalt oxide is proved by the bead being bright yellow while hot.* The identification in this way, of a bead colored with a roughly estimated percentage of any mineral (a "trace" of most powders generally \doteq .5 mgrs.), is not, however, as I would again beg the reader to remember, to be taken as determining any particular *mineral*, but only certain chromatic constituents of that mineral, which are known, or may, after long practice, be thus inferred to exist, combined in it, in certain proportions.

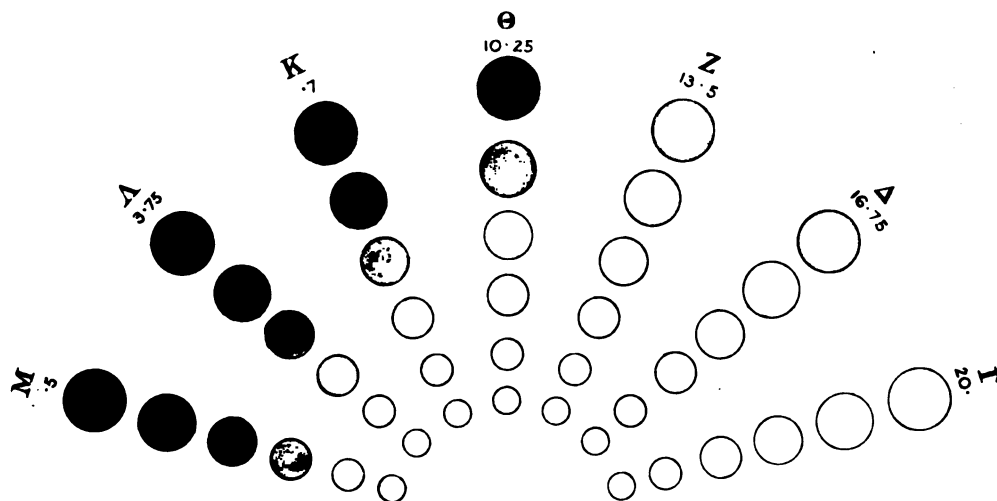
(129). PYROCHEMICAL MANIPULATION.—Although part of the information under this head has been already given under that of *Matériel*, &c., it will be better to repeat than to omit anything, and more convenient for the worker to have the whole collected in one paragraph; while it must be remembered that, as the indications given by these methods are more delicate and minute than those afforded by chemical analysis in the "wet way," so greater care and attention to *minutiæ* are required on the part of a successful operator.

(a). *Pulverization*.—It is simply impossible for perfectly pure results to be obtained in any operation which has necessitated "pounding" in a mortar, or even grinding in an old agate (far less porcelain) mortar; nor can such fine powder be obtained thus, as by the following process: (1) Place the substance or essay on the agate slab, between the polished steel jaws of the (α) forceps; the first two fingers of the left hand resting lightly over them to prevent loss from jumping out of fragments. Crush the large fragment, and then the small ones two or three times with this, until all are in a *coarse* powder. (2) Place over this powder one or two drops of distilled water (which prevents all scratching of the polished agates), and with the other agate slab press heavily down on the moist mass, when even corundum at once gives way; if any largish fragment resists this pressure, crush it again with the (α) forceps. When the powder is crushed thus, it will be moderately fine, and the grinding process is then begun,

* Vide 'Proceedings,' Royal Society, vol. xx., p. 469. I still possess this bead.

NORMAL COMBINATIONS.

Plate :



Black or M = .5, because there is no black which does not reflect some light.

White or Γ = the Sum of all prismatic tints and black. 20 as follows,

Black	-	.5
Blue	-	1.0
Yellow	-	2.0
Red	-	3.

Sum of the decimal tints between = 13.5
White - 20.0

by rubbing one of the agates over the other. Remember here that great or even moderate pressure is not now required, and that most substances yield a finer powder if scarcely any pressure beyond that of the weight of the agate is added. The *feeling* informs any but a clumsy operator when he has got the finest possible powder. In this case the agates seem to stick to one another, for there is now a paste between them. (3) Press the clean broad end of the platinum spatula in the middle of this paste, and dry the portion so obtained, by heating the other side to redness in O.P. (4) If the operator wants more of the powder, he can thicken the paste on the slab by scraping it together with the *hot* spatula, when the water soon evaporates; if what he has first taken on the spatula is enough, he must scrape the dried paste gently off that on a clean agate slab, with the clean smooth back of a penknife, or even with the edge, if it be held slantingly. (5) Agate slabs, if *very* dirty, are cleaned in the same way as aluminum plate, or platinum, &c., foil. It is thus evident that neither hammer nor anvil is required for crushing substances to a fine powder; and in the same way, by squeezing them with the (α) forceps, it can be proved whether metallic balls are malleable or brittle; instead of by the clumsier and slower process of hammering them under a piece of paper, as is usually done.

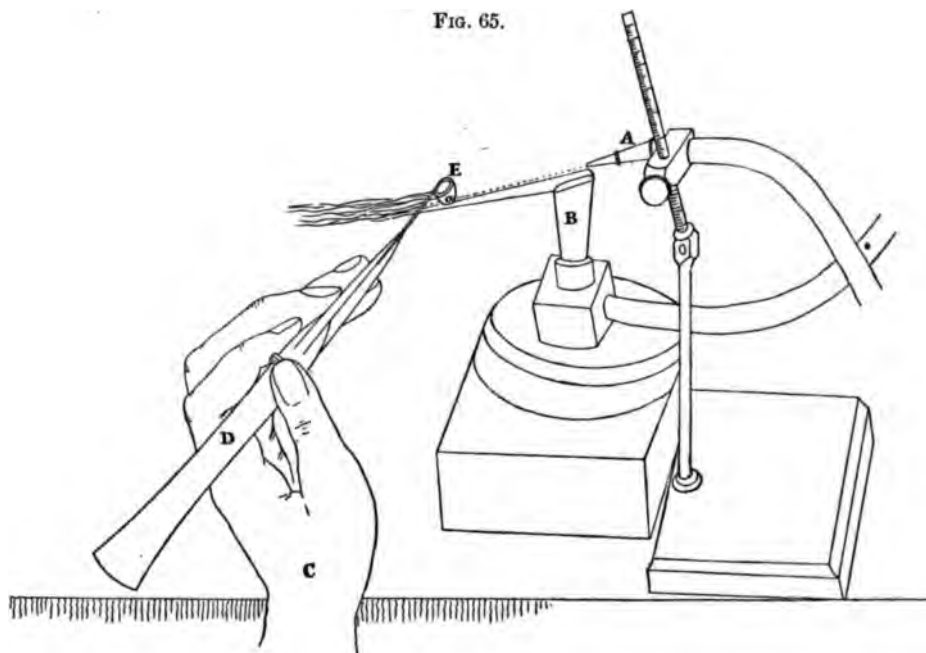
(b). *Attacking Substances qualitatively.*—There is one enormous advantage possessed by pyrological qualitative research over chemical, or that by hydracids, which may be expressed by the one word *minuteness*. Most pyrological operators, indeed, have thrown this advantage away, from the idea which, in chemistry, is generally the expression of a fact, that it is necessary first to dissolve a considerable portion of the substance before it is possible to obtain any of its reactions. Thus "a trace" of the powder is taken up on the borax or microcosmic-salt bead, and nothing further observed in its treatment beyond effervescence, &c., until it is completely dissolved. I *weighed* one of those "traces," which I had been in the habit of thus taking up for ten years, and found it was about 5 mgrs.! As the ordinary beads weigh about 50 mgrs., this "trace" is 10 per cent. of the solution. Thus all chance of the separate reactions of constituents being observed is lost and confounded in the general *melée* which takes place in solution; and if there are two or more chromatic oxides in the substance, the color of the most powerfully chromatic one alone prevails. I do not mean to say that the fluxes above mentioned would give at any stage valuable indications; and that is the very reason I discontinued their use. What would the chemist say if he were asked to commence attacking a substance, not with nitric acid, but with sodic nitrate? There was no prescience required, therefore, to foresee, as I was fortunate enough to do first, that by

using pyr acid alone for a solvent (like the chemist), I should obtain *that* set of reactions; and, *in addition*, get those of the alkali, afterwards added. For some years, however, after making this simple discovery, I still persisted in taking up the "trace" (of 5 mgrs., which now appears more like a cart-load than a trace), and in making no observation previous to complete solution of the substance. It seems evident that if the operator commences with the smallest possible quantity of substance which will cohere, so long as he can see it to take it up without a lens, he has the advantage of observing those minute reactions, *in addition* to those of any larger quantity he may afterwards treat; whereas, if he *commences* with a large quantity, he obtains only one set of reactions instead of two. What I mean is, that if an operator could treat thus a simple molecule of the substance, he would evidently have a great advantage over one who could (or would) only treat a hundred molecules combined. No operator can gain this advantage, but he can gain an approximation to it by treating the smallest possible mechanical division gently, and watching for results. For instance, let us take a crystal of *Jeypoorite*, which is about the size of quarter of a small pin's head. The clumsy operator will, as I did at first, crush a number of these crystals, and apply "a trace" of the powder to a glass or bead, which is colored violet or blue, according to the acidity or alkalinity of the flux used, by which means he obtains a reaction for cobalt oxide only. Having become more careful or knowing, as I afterwards did, he applies only a single crystal to the glass of H^{P} at bottom (*a*) (Fig. 65); heats that very gently, and examines the result momentarily in the cold glass. He finds a yellowish-red streak has been emitted by the crystal, the yellow part of which streak he easily proves to be due to sulphur. A second gentle heating makes the streak enlarge to a mucous-like matter, which shows him, when he is initiated in this mode of analysis, arsenic or antimony; perhaps both. By means of his nose he satisfies himself of the presence, first of sulphur, then of arsenic, while that of antimony is doubtful. By further heating in O.P., he finds that cobalt is the predominant base, from the color afforded, and obtains a fair (though rough) estimate of the *amount* of that cobalt, from the *tone* of the violet (assuming phosphoric acid to be the flux used) given; for violet, being a "secondary," or compound color, is susceptible of *tone* by further addition, which blue, being a primary or pure color, is *not*; and as the latter color is afforded by solution in borax or microcosmic salt, no rough idea even can be formed from the blue color produced, as to the quantitative value of a cobalt ore.

(c). *Manipulation of Platinum Wires*.—Only those who have to find it out, find how much is contained in an apparently trifling act or fact. Some modern chemical works advise the operator to fuse platinum wire into a glass handle;

and one I have says, it is "unfortunate that platinum is so soft;"* but it is an ill wind which blows good to nobody, for this "softness" is of the greatest advantage to the pyrologist. He straightens and cleans his wires by a species

FIG. 65.



Mode of detecting a Trace of Arsenic or Antimony, &c., in a Silver, Cobalt, Nickel, or Copper Ore.

A. Jet of a Table Pyrogene.

B. " " Gas-pipe.

C. Position of left Hand, resting on a Table.

D. The (e) Forceps holding Essay Wire.

E. The Essay Bead of Phosphoric Acid.

a. The Essay.

of wire-drawing and squeezing the end, heated to redness in a gas or spirit-lamp flame, in the (e) pliers; and *unrolls* the wire from the glass or bead with the right-hand forefinger and thumb by means of this very "softness" of platinum. Berzelius tells him to preserve, or get rid of the bead, by jerking it off the wire when red hot—a difficult, and, if there is no aluminum or zinc tray to catch it when it falls, a dangerous process; for the red-hot bead will take up a portion of almost any other tray, and sticks to one of platinum. By forming where possible, "glasses" instead of "beads" of boric acid, the operator saves, in a morning's work of four hours, at least an hour of *time*, and perhaps a couple of hours of *patience*. If he fuse the wire into a glass handle, as recommended, he will not get one hour of real work out of the four. *Ends of wire can be sold, i. e. exchanged, for half their value, in weight of new wire.*

* Platinum wire, notwithstanding its apparent softness, scratches the smooth inside surfaces of German silver pliers when drawn through those for the purpose of cleaning it. The term "softness" seems confounded by this writer with pliability.

(d). *Manipulation of Aluminum Foil, or Plate.*—This beautiful metal is considered to be far superior to platinum (except in the case of wires which cannot usefully be made of the former metal) for pyrological purposes, for the following reasons: (a) It is much lighter and therefore proportionately cheaper and more portable. (b) It alloys with none of the volatilizable metals, as Lead, Arsenic, &c., which can, therefore, be treated *directly* upon it, without fear. (c) It removes heat so rapidly, by its great conducting power, from the under part of an essay supported on it, that the most fusible compounds are unable to fuse upon it; as, e. g. *Cobaltite*, *Galena*, and even *Stibnite*, which may be heated upon it without “sintering”; that is, without the formation of obstinate arsenides or sulphides, but the volatilizable part can thus be gradually expelled, leaving the nearly pure oxide of the base or bases. In this way, green capillary nickel oxide may be produced in *Smaltite*. This heat-removing property can be proved by heating a boric acid bead on platinum wire white hot in O.P., just above a plate of aluminum, which is rapidly touched by the white-hot bead, when, the O.P. being stopped at the moment of contact, the *upper* part of the bead and platinum ring begin again to glow after having ceased, and continue to do so for some time after, while the under part remains comparatively cool. The aluminum *spoon* is made by flattening one end of a .1 inch or 3 mms. thick wire, and punching a slight cavity in the flattened part. It is especially useful for applying cobalt or manganese solution to heated substances. The latter (manganic sulphate) forms a plating on it as white as silver, which does not seem to interfere with its usefulness. In this spoon, an oxide or metal shows its combustible color better under O.P. (so far as my experience goes) than on any other support; the reason apparently being that, as the heat is carried away from beneath, there is a comparatively *cold* side of the essay, and that cold side repels heat upwards where the O.P. is acting, the heat of which latter, therefore, is not merely concentrated on one corner or point, but actually increased from the essay itself. At any rate, the top of a ball of silver, for instance, may be burned so as to show a pyrochrome, while the under part is scarcely in fusion at all. The essay should be as large as a pea, and heat applied only at top.

(e). Aluminum plate, when used for sublimation, and not new, is first smoothed with the (γ) forceps under a flannel cloth; then scoured clean with a square inch of moist emery cloth, wiped dry, and one inch at an end, bent on a table at an angle slightly less than a right angle, as a ledge, to hold the essay; after which, two inches inside the angle are burnished with ivory. If emery paper is not at hand, a small fragment of flint crushed with (α) forceps and ground to paste between agates, with three or four drops of water, will answer. The (θ) pliers, if not ready for use, are to have their steel legs rubbed slightly

with fine emery cloth, moistened; they are then to be burnished bright with the back of the (γ) forceps, and fastened on the aluminum plate about two inches above the essay (the plate passing up to the felt-covered shoulders of the pliers); before placing which, an O.P. is to be directed on the plate, to see if it is clean; if it is, there will be no change on the burnished upper leg of the forceps. The upper as well as under part of the plate can be slightly bent over to better catch any smoke or exhalation which may rise, so that it forms the arc of a large circle, but it is better to have only one lip or ledge projecting at bottom, *at less than a right angle*, about an inch. The essay for this purpose should be rather large (about the size of a small pea), but only a slight O.P. is first applied to the top with a mouth pyrogene, so that, in fact, only a very minute portion of the substance is really treated, especially when it consists of very volatile oxides as mercury, or when sulphur is to be detected by smelling; for the reason of this, *vide (d)*; but platinum foil is best for this.

(f). Almost the first thing the operator ascertains by the use of this apparatus is, that those who have used charcoal for this purpose, have completely lost the observation of an important sublimate, which most metals of this class give under O.P. They have failed to observe it, because it is black, and could not therefore be detected on the black charcoal. I append here, for reference, a table of reactions of some of these metals treated on this apparatus. But the first observation is, or should be, of the burnished leg of the pliers. If the O.P. has been ever so slightly directed thus on one of these metals, the leg is found covered with irregular spots, arranged precisely like those on the skin of a leopard. With a momentary O.P., which should be always used first, and the pliers then taken off and examined through a lens, the spots are invariably found to have metallic lustre, and iridescent tints. Some are small, others large, or sized between these two. Antimony affords these iridescent spots so rapidly, that for some time I thought most substances thus essayed contained antimony, but finding that those, and all of this class of metals, reddened blue litmus paper moistened, or were in fact due to an acid exhalation, I obtained them from a piece of fresh charcoal, although, as before stated,* the clean aluminum plate afforded *none*. The conclusion seemed evident that they are due to the acid oxide of the substance. I then tried thus, a small piece of very pure crystallized sulphur; the acidity of the spots given by the sublimation of this last was very *strong*, while that afforded by those of other substances was comparatively weak. The leopard spots, therefore, are apparently due to the formation of a thin film of sulphate, carbonate, arsenate, antimonate, &c., of iron upon the sensitive polished steel, having, when a drop of diluted water is added,

* Paragraph (129, c).

a little free acid. If *two* drops are added, the acid reaction of the same oxide will be less strong. This is the way to manipulate: The spotted pliers are removed from the plate of aluminum, a drop of water is placed on the spotted leg, and a small square of blue litmus paper rubbed over the watered leg with the point of a needle or with pliers, not with the hand, which might afford acid matter. Every sublimate deposited here would appear to be acid, which fact derogates from the importance of the reaction as a test; but as the upper part or white border of most sublimates on the aluminum plate itself is soluble even in cold water, the greater acidity of the solution of some, as, e. g. of arsenic and antimony, serves to distinguish those from other sublimates; that of zinc, for instance.

(g). Metals affording a sublimate. This class of metals is subdivided, for convenience of examination, into—

(a) *Volatile Metals*.—Mercury, Arsenic, Zinc, Molybdenum, Cadmium.

(β) *Volatilizable Metals*.—Antimony, Bismuth, Lead, Silver, Gold.

It will be observed from the careful perusal of the annexed table, that the operator this way has a threefold advantage over the one who uses charcoal. (a) He has an extra sublimate, a black one, from many metals, not observable or not formed on charcoal, and although there is an apparent similarity between the black sublimates of all metals which yield it, they react differently in H₂. (b) As some volatilizable metals volatilize before O.P. with difficulty, and very slowly *per se* on aluminum plate; while others, as zinc, arsenic, mercury, rapidly sublime in the same situation, the operator can evidently thus, in a great measure, separate these. But the first class, which includes even such a volatile metal as antimony, can be easily made to sublime by slipping a flat piece of charcoal or charcoal paste, about twice the superficies of the fragment, and the tenth of an inch (3 mms.) thick, underneath that, and treating with O.P.; when even more “smoke” seems evolved than by using charcoal alone as a support. He can thus in a combination of these classes of metals, obtain the sublimate of the second mentioned, after he has got rid of that of the first; and there is, as is well known, a third class, such as tin, which oxidizes under O.P., but does not sublime, even held on charcoal. (c) To waive the fact that the polished steel, pointed downwards towards a window, is an infinitely more delicate detective of small quantities of sublimate than glowing charcoal held in the line of fire can possibly be, the operator thus, has (thirdly) the enormous advantage of effecting changes of *color* by the application of O.P. or H.P. to the sublimate already formed on the aluminum or steel. Thus, in a moment, he tells whether a white sublimate is due to arsenic or antimony, for O.P. reduces the latter to its black oxide again, while it completely volatilizes the former. Again, the yellow sublimate of lead on aluminum foil, when that is heated by a P.P. becomes brown;

TABLE IV.—SUBLIMATING REACTIONS OF PURE METALS ON ALUMINUM PLATE.

	SOLVER.	TIN.	ASBESTIC.	ANTICOR.	BARYTH.	LEAD.
	Reduced from the Nitrate.	Freiberg Test Tin.	Native (Freiberg).	Test, R.A. Inst. Labor.	Test, R.A. Inst.	Freiberg "Proust Bel."
1. Burns (pyrochrome)	Strongly heated = H β Moderately " = Ca	= (G).	= (G β d).	= (E β d).	= (G).	= (G).
2. Smokes	Nil.	Nil.	Strongly, with gar- lic smell.	In cooling.	Nil.	Nil.
3. Ditto, on mortar ..	Golden sublimate. Rose by slanting light.	.. ..	Ditto.	Strongly.	Gives (6), (7), and (8) sublimates. Slightly.	Strongly, with (6), (7), (8), and (9) sublimates. (?)
4. Smells .. ..	.. ..	.. ..	Garlic.	Indescribable.	Burnt bones.	To a ball.
5. Fuses	To irregular mass, with shell-like oxide over it.	To a rough ball, coated with dark grey oxide.	Not at all.	To a round mass.	Instantly to a ball.	
6. Black sublimate	Small egg-shaped pieces of silver, scattered upwards in great profusion.	Slight; under; in front.	Just above assay.	Below assay.	Slight, above assay.	Just above assay.
7. White ditto		Very faint; over the black.	Crystallization be- low assay.	Above; not crys- talline.	Faint, above black.	In round spots, and bluish on edge.
8. Yellow ditto	Golden, met. lustre by direct reflected light.	Nil.	Nil, unless S be present.	Nil, unless S be present.	With C, strong; without, very faint.	Faint, above black. With C, strong; nil, without C.
9. Brown ditto .. ..	.. ..	Nil.	Ditto, ditto.	Nil.	When (8) is treated with O.P.	When (8) is treated with O.P.
10. Red ditto	H β by slanting reflected light.	Nil.	Ditto, ditto.	Nil.	Nil.	Nil.
11. Steel forceps ditto (leopard spots),	Small, pale copper color.	Iridescent, mode- rate large.	Blue, smaller than Sb ones.	Iridescent, mode- rate large.	Small, very distinct.	Iridescent.
12. Ditto, white subli- mate.	Nil, with C.	Nil, with C.	Copious, spots whitened.	Slight; with C, copious.	Brownish.	Ditto.
13. Ditto, brassy ditto	.. ..	.. ..	Nil.	.. ..	Moderate.	Nil.
14. Ditto, water on ..	Moderately acid.	Moderately acid. (6) and (7) do not brush off; from the ore, they do.	Strongly acid. (7) does; (6) does not.	Strongly acid. (6) and (7) ditto.	Faintly acid. (6) and (7) do not.	Slightly acid.
15. Foul, brush off ..	.. ..	Velvety black.	Black. Vanishes.	Brownish black. Turns black.	Yellow. Turns brown.	Unchanged.
16. Under assay	Irid. met. lustre.	.. ..	.. ..	.. ..	.. ..	.. ..
17. O.P. applied to (7) and (6).	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
18. H.P. ditto ditto ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..

and I have little doubt that this reaction has often been attributed, as it was at first by myself, to the presence of cadmium in pure lead, as *probir blei*, when the former metal was not really present. Thirdly, arsenic deposited *over* antimony, is black; antimony over arsenic becomes metallic by O.P., &c.

(h). *Manipulation in Sawing Mortars, &c.*—Screw a thread saw into a geometrical pen; teeth of the saw up; back of the saw over (not under) the screw. Take the piece of charcoal with the thumb and middle finger of the left hand, the *first* finger being gently pressed on the other end of the back of the saw, as it has passed through the charcoal, so as to keep it down. The charcoal should be sawed over a sheet of paper, and the powder kept, if required for making paste. It is an extremely dirty and inconvenient support, in the shape of the large prismatic blocks at present used, and should be dispensed with as far as possible by the traveller. The mortars when cut, should be kept in a japan tinned box ready for use.

(i). *Manipulation in obtaining Colored Flames, or Pyrochromatism.*—A colored flame is here called a *pyrochrome*, because it is an advantage, wherever possible, to use one word for two. Pyrochromes are obtained in two ways: (a) by heating a largish fragment of the essay on the aluminum spoon with a powerful O.P., and (β), by touching the wick of a pyrological candle with it, while yet hot, as in the Ellychnine pyrocone. In the first case, the colored light seems due to the actual combustion of the substance itself; in the second, to the partial decomposition of the blue, or hydrocarbonous pyrocone. The mineral *Barytocalcite* affords a good illustration in support of this hypothesis; by the (a) manipulation it affords the green pyrochrome of barium, and is found to have lost weight. By the (β) manipulation it affords the red-orange pyrochrome of lime for half an hour without losing weight. Caustic lime seems to have an attraction for part of the carbon of the hydrocarbonous pyrocone, but not to be able to retain it, for a black spot appears on a fragment in a good H.P. towards the front, which disappears on the removal of the fragment from the flame. If fluoride or chloride of calcium be held instead of lime in a candle H.P., the carbon is retained, probably as fluoride or chloride of carbon, which is incombustible in that situation; the former appears as a green, the latter as a black round patch on the fragment, both in front, while the intensity of the red pyrochrome is visibly augmented. If this hypothesis be true, the blue pyrocone is tinged with red, alternating between (H) and (D) on the plate, or between violet (which, by the way, is the color of the pyrochrome of pure charcoal wetted with distilled water) and orange, which is the color of the pyrochrome of chemical water. The reason then why chlorides, or substances moistened with hydrochloric acid, augment pyrochromatic intensity, seems to be the *retention* of part of the carbon of the blue flame, as chloride of carbon, so that the intensity of color appears to be increased by the

increased *durability* of the phenomenon. That lime decomposes the hydrocarbonous pyrocone, and abstracts part of its carbon, may (as seems to me) be proved by the following simple experiment.—(1) Direct a pure (blue) gas H.P. upon the clean polished aluminum plate; no stain is left. (2) Place on the same spot a fragment of pure calcic carbonate, and direct a similar H.P. upon that; so long as the orange pyrochrome is emitted and impinges on the plate, no stain is left there, but as soon as the lime, becoming caustic, glows, a black carbonaceous stain gradually spreads round the fragment on the plate. On the upper part, where the red pyrochrome impinges, a white metallic-looking stain is left. Let the operator, in another case, prepare a pure blue pyrocone, by putting plenty of wax in the disc of an ignited pyrological candle, the wicks of which must not be too much carbonized, i. e. the top should be trimmed with scissors. He should then hold a paste of lithic carbonate in O.P., almost in P.P. A faint (D) pyrochrome only will be observed. If he advance the essay just within the tip of the blue, the pyrochrome produced is (C) or red-orange; almost precisely that of lime. Advancing the essay now into H.P., he finds the pyrochrome (H δ) or violetish-red, about the usual color of a strawberry. Lastly, touching or almost touching the wick, the magnificent (H β) or red-violet is obtained. These phenomena seem to me to offer to the candid observer clear proof of the different effects caused by the decomposition of different parts of the blue pyrocone. If the color were produced by the simple combustion of the lithia, as is generally supposed, there could evidently be a change only of intensity, and that intensity would as plainly be increased by more rapid combustion. But exactly the opposite is the case; the least intensity of color is afforded at the hottest point of the pyrocone (*a*) (Fig. 12) where the lithia is most rapidly volatilized; while changes in color are caused solely by corresponding changes of position in the blue pyrocone. The attraction lithia has for carbon may be seen by holding the red-hot fused paste in the luminous part of the candle, when the mass turns quite black, but becomes gradually white in cooling; a combination with the carbonic hydrate (soot) having apparently been formed; fresh lithic carbonate *retains* this soot in cooling.

The lithia paste held *on* the wick becomes after a short time perfectly black from the carbon absorbed, the (H β) pyrochrome becoming, as might be expected, proportionately faint. Soda also gives a deeper toned orange (D) pyrochrome in proportion as it approaches the wick, but when it is held on that absorbs little carbon, and the (D) color, therefore, is little diminished. Potash alone affords a pyrochrome of almost equal intensity in O.P., in H.P., and in E.P. In a good H.P. the potassic mass rapidly becomes coated with a grey metallic-looking film, and when the wick is touched with this coating the reaction of a metal is produced. *Vide (k)*.

Two things should be observed in watching these pyrochromatic effects. (a) That it is only the blue colored flame which affords them. (b) That the colors afforded are invariably *prismatic* combinations; that is, they are never such as are shown in Plate II. By playing a good blue pyrocone backwards in a pyrological candle over the melted wax, a violet pyrochrome, almost the counterpart of the potassic one, is obtained.

(j). *Manipulation of the Pyrological Candle* (Fig. 6).—The zinc cap is taken off, a little wax melted in it over a spirit lamp, and the candle stuck into the melted wax, and allowed to cool thus, for the purpose of forming a "dead head."* When cool the candle is taken out of the cap, and placed in it again with the required slant. The wick is then lighted, the flame blown out when the former has blackened and absorbed some wax, and cut with the (κ) pliers so that it appears just .1 inch or 3 mms. above the zinc collar, viewed from a level. The candle is then relighted, and a momentary pyrocone made to play with a mouth pyrocone *backwards* over the unmelted wax and the back of the zinc collar so as to slightly warm it, by turning the candle gently round with the left hand, the right being crossed over that, when the slanting position of the candle causes the melted wax to flow to the wick, which is thus thoroughly saturated, and will now produce with a mouth pyrocone a perfectly pure blue pyrocone, without even a tinge of violet in the O.P.; this is apparently due to excess of hydrogen; luminosity to excess of water; the last is much the worst impurity, but both should, if possible, be avoided. By placing at the back of the wick pieces of powder of fresh wax, or of the cake which has dropped down the candle and congealed at the foot, carbonization of the wick can for a long time be prevented; but when it requires cutting, warm the zinc collar all round very gently with a back pyrocone as above described, when it will be possible to slip it down the candle, which is then to be blown out, the wick cut level with the collar, *always square, never slanting*, and that slipped the required distance (3 mms.) down the candle. The part of the collar next the wick is of course slightly hot, and should be kept as cool as possible by bending the wick inwards, but seldom so much so as to melt the wax underneath at that part, and thus allow that above to escape down the candle, as "guttering"; but it sometimes happens that the fragment of a decrepitating mineral which has been tried in the Ellychnine pyrocone drops between the wick and collar, and, by the time it takes to cool, creates a space there, which, when fresh hot melted wax comes, is apt to create guttering, when the whole of the melted wax in the disc sometimes escapes, and pours down the candle on the table as a small lake, which, however, instantly congeals to a cake without soiling anything. When this

* Paragraph (80).


occurs, blow out the candle, take up the cake with a knife-blade, break it in pieces, and putting those at the back of the wick, play on them with a back pyrocone as above described, until a melted surface is produced on the disc. This should sometimes be done on purpose, in order to drain the disc, and thus discover, on the white cold wax underneath, any mineral or metallic fragments or powder which may have fallen, and which are to be scraped away with a penknife.

(k). When the wick of one of these candles is touched with clean new platinum in E.P., a sudden blaze of luminosity is produced, and this phenomenon seems characteristic of all metals, but most require heating in the first place. Potash coated with a metallic-looking film in H.P. also produces this effect.* See also the directions for using the prismatic or tablet candle,† which differ in some particulars from these.

(l). *Manipulation in Boiling, Decanting, Filtering, Evaporating, &c.*—It is often necessary to boil silicates, &c., in distilled water with crystalline boric acid, in order to separate bases for further treatment in an $\text{H}\ddot{\text{B}}$ glass or bead; also to boil that, in order to extract the contained balls, &c.‡ In thus operating, the Berlin dish should always be held in the (η) pliers, and never placed on a stand. It is also better to avoid the use of a platinum capsule or other cover, because the progress is then concealed. When the residue and solution appear distinct, rest the dish on the table; draw up the clasp wire, which frees the pliers, take up the dish in forefinger and thumb of the left hand, and gently tap it with the hilt of the pliers held in the right, in order to determine fine precipitates. Then *decant* the solution (if not required further); but it is always best to put a drop of it on the agate slab for examination in $\text{H}\ddot{\text{B}}$, as follows: Turn the dish, held slantingly with the points of the thumb and fingers of the left hand, while the *little* finger of the right is gently applied to the edge of the dish from time to time, so as to withdraw by cohesion the solution collected there by drops at a time, which fall on the floor. By turning the dish in the left hand, precipitates of different specific gravities may be separated sufficiently to examine each separately in $\text{H}\ddot{\text{B}}$. When thus, only a drop of solution is left, that can be removed by a slip of blotting paper about 3 mms. wide. The precipitate should then be boiled in fresh water at least once, and that removed as before, when (for qualitative analysis) a portion can be taken out with the clean point of a penknife and placed on the slab for further examination. Balls and fragments are removed by tilting the dish over on a blotting pad,§ and this may also be done in the case of flocculent precipitates (generally what the chemists call hydrates), which are suspended in the solution, but fall when that cools,

* *Vide* Paragraph (129, i). † Paragraph (79). ‡ *Vide* the several heads. § Paragraph (97).

perhaps on a heavier insoluble precipitate. In this case, the first (which must of course be gently poured on the pad) can be separated from the last, and obtained from the pad, which rapidly dries, by brushing it off with a fine hair pencil. *Evaporation* and *ignition* are only required to obtain a paste as a powder, and should never be effected in a dish, but on the platinum spatula.*

(m). *Manipulation in Crystallizing Substances pyrologically, or Crystallignation.*†—A flux should be made by adding about one-third of the weight of powdered fluor spar to a bead of phosphoric acid, which combination affords, after P.P., a clear, highly refractive bead. A trace of silica or alumina added to this, dissolved in O.P., and the bead then briefly treated with H.P., immediately induces crystallignation. In the first case, large (compared with the size of the bead) white opaque prismatic crystals, with slightly pointed ends like maggots, cover the bead inside and out. In the latter case the crystals are sometimes crossed, and, with a large trace of alumina, well dissolved by strong O.P., and the bead then treated with P.P. and lastly with H.P., some beautiful crystals, crosses like those of *Staurolite*, opaque white in the clear and brilliant bead, appear. In both cases, tabular four-sided prisms, , apparently due to fluorine, appear *on the surface*.

Crystallignation may also be rapidly induced by applying to the anhydrous calciboric ball,‡ held *per se* on a platinum ring, a small trace of fresh, slightly calcined lime, silica, alumina, ceric or didymic oxide, or other earth under O.P., when small transparent sphericles are ejected, which first glow white hot in the O.P. like little stars. If these are caught on paper, and one of them applied under O.P. to a calciboric ball, apparently anhydrous crystallignation is instantaneous, and spreads over the whole ball with marvellous rapidity.§

Crystallignation may be induced in platinum by fusing it before O.P. with about its bulk of phosphoric acid which has been previously made into a bead on clean new charcoal, a proportion of which is evidently dissolved in that. The resulting platinic ball is kept as far as possible covered with the flux, and the whole mass allowed to cool slowly. On extracting the ball from the bead (which is easily done on account of their differing rapidity in cooling) the surface of the former, where it has been covered by the latter, will be found to consist of more or less crystalline planes, the nature of which has not yet been determined. Crystallignation seems also inducible in gold by fusing it on a charcoal mortar over aluminum with .5 per cent. of pure silver and an equal proportion of test lead.

* Paragraph (129, a).

† From *Ignis*, fire. Some distinctive term from water crystallization seems required, or at least convenient.

‡ Paragraph (65).

§ Vide also Paragraph (229, d).

(n). *Manipulation to obtain from Substances a characteristic Smell.*—Place the fragment or powder on the aluminum spoon,* and cover it for some seconds with a pure blue H.P. from a pyrological candle (when the characteristic pyrochrome will often be observable). While the essay is yet hot, place a drop of water on it with the bottle (Fig. 24), and allow the steam to escape up the nostrils. By this operation some sulphates as *Barite*, *Celestine*, and *Alunite* afford the H.S. smell: others, as *Gypsum*, *Epsomite*, *Aluminite* do not, but, on the other hand, each of these yielded its own peculiar smell, which, as I have smelled nothing to compare it with, I unfortunately cannot describe; sometimes I fancied it like soup, at others, like soap, &c., but this much is certain: (a) That each smell can be recognized by the operator who has once smelled it. (β) That none of these latter smells were so bad as that of H.S. (γ) That they are different from that of their pure base, treated similarly. After saturation with water, the essay is to be again slightly heated with H.P. (not O.P.), so that steam again rises, which is again smelled. N.B.—In the above operation silica and alumina blacken; † glucina and zirconia do not, even when combined with silica. Erbium blackens; yttria turns greenish-brown, if those specimens examined, the first from the British Museum, the second from Görlitz, be pure. All sulphides are easily thus distinguished by the pungent well-known odor they emit on an aluminum spoon after a short H.P., when of course no water is to be added.

(o). *Manipulation in Vesiculating.*—The operator first puts the (γ) jet, ‡ which has a large bore of 1 millimetre, on a mouth pyrocone; and with a large, i. e. long and therefore yellow natural pyrocone—if it be of coal gas, the amount of flame workable being proportioned to the diameter of the orifice of the jet—prepares a bead, not a glass. In using this large orifice jet the cheeks are scarcely at all distended; after a little practice it is very easy to use, but at first seems difficult. The fact is too much effort is made by the beginner; there must be no *blowing* at all, but the breath merely suffered to glide through the pyrocone, so that a very short obtuse pointed pyrocone is produced. This short pyrocone, however, has tremendous power, and volatilizes a bead of boric acid in half the time the pyrocone produced by the ordinary jet can.

(p). The state of heat in which the bead is to be blown into, depends upon its fluidity. It answers to keep a bead of boric acid, which is very viscid, waiting some time, but when potash or soda is contained, the bead should be vesiculated while red hot. That process with the (γ) jet is very easy; it never fails after the first few attempts, and the only thing the operator has to avoid is blowing too hard, when the vesicle bursts with a slight report, but will still do

* Paragraph (93).

† Paragraph (73).

‡ Paragraph (81).

for breathing on. There are two ways of doing this: (α) the jet can be applied to the platinum wire ring, and the breath thus sent *inside* the vesicle; or (β), that is breathed on in the open mouth; (α) vesicle steams slightly when a spirit lamp is applied underneath, but (β) method is the most delicate. The mode of procedure is this: two vesicles are made of $\text{H}\ddot{\text{B}}$, in one of which a speck of potash, the size of a small pin's head, has been melted. These vesicles are held in different pliers, but close together, and breathed on in the open mouth. The pure $\text{H}\ddot{\text{B}}$ vesicle has a clear blue appearance; the other is dim, like breath on a pane of glass, and bluish. Still holding the vesicles together, a small lighted spirit lamp is passed about four inches beneath. The cloud will fly from both, but if properly held the $\text{H}\ddot{\text{B}}$ vesicle will shrivel, but the other will remain almost intact. The reason of this seems that the small portion of potassic borate formed communicates a texture to the vesicle something like glass, so that it resists heat better than the pure $\text{H}\ddot{\text{B}}$ vesicle. Unfortunately, however, blowing through the large-bore jet not only communicates extreme fluidity to beads fused before its pyrocone, but seems to change their chemical nature, giving to a pure $\text{H}\ddot{\text{B}}$ bead some of the properties of $\text{H}\ddot{\text{B}}$ + a trace of potash; while an $\text{H}\ddot{\text{B}}$ bead with a trace of soda contracts a slight cloud when breathed on. It is therefore better to fuse the essay with the small orifice or (α) jet, and to vesiculate the bead with the (γ) jet. The ring of the wire must not be too large. The vesicle, fresh made, should not show too much iridescent color, which is a sign that it has been too thinly blown; a defect which arises either from too violent blowing, or from waiting until the bead was too cool, when part of it adheres to the wire, the other part being blown out too thinly. If a table pyrogene is used for fusing, the hand pyrogene with a large orifice jet must be ready at the right hand of the operator, who has ample time to drop the bellows of the former, and take up the latter before the bead cools too much for vesiculation. The bead is to be held in the left hand, hanging like a bag from the wire ring, the diameter of which is to point upwards, and *not* to be held sideways, while the large orifice jet is pointed downwards upon the bead, which, in fact, is to be blown *downwards*. I find this test not so delicate at the sea-level, as it is in the Himalaya Mountains at 7000 feet elevation; still he must be a dull observer who cannot see the difference caused by breath on an $\text{H}\ddot{\text{B}}$ vesicle containing a trace of soda, and one containing a trace of potash; and it is good exercise to apply the latter to the former, vesiculate, and breathing again, to note the change.

(q). *Manipulation, General, Rapid, of Minerals, &c., in the Field.*—Place them in four paper boxes or parcels, numbered 1, &c., according to the following arrangement:

Class (1), stony but heavy (most often black-grey; next often red-brown).

Class (2), metallic looking and heavy (most often yellow; next often yellowish-white).

Class (3), vitreous or earthy, and comparatively light (most often white; next often whitish-yellow).

Class (4), soft, earthy (most often black; next often brownish-yellow).

Scales of hardness seem ingenious, but when one reflects how little they are appealed to, even by rough examiners, as miners, who go no further, we soon see that they are almost useless. Indeed, if scratching minerals with one another, or worse, with the *same* penknife point, which is of course slightly turned by the first mineral, and then affords a *very* different test for the second, could give an *exact* idea of the nature of a mineral from its hardness, there would be no necessity for further analysis. Extreme hardness and extreme softness, however, are readily appreciable without the aid of any scale, and are pretty certainly indicative; the first of gems or of quartz in some of its varied forms; the second of a hydrous silicate, with generally magnesia or alumina as base, and a quantity of "organic matter" and nitrogen.

With Classes (1) and (2), first, heat a fragment the size of a large pea *through* platinum foil, as shown in Fig. 55, but so slightly as to stop short even of making it decrepitate, if liable to that malady. If mercury is contained in the mineral, the side in contact with the platinum will be covered with a beautiful snow-white sublimate like hoar frost (given by no other metal except tin, which is determined by further heating), unless organic matter is also contained, when this will be black; as in hepatic cinnabar, which, however, on being further heated (on aluminum foil, as platinum would be attacked), yields the *second* or metallic sublimate of mercury, which, though appearing like an ordinary sublimate, is found through a powerful lens to consist of millions of minute balls, which are scraped together in the ordinary way. The *first* sublimate, which I discovered in April, 1874, by heating mercury on aluminum plate, can *not* be scraped into balls.* Sulphur is detected simultaneously by the pungent smell; arsenic, if much is present, by a white crystalline formation on the heated side of the fragment. Next, if the mineral decrepitates, cover the fragment in the same place with distilled water, the lip of the platinum tray being turned up to contain that, and boil the fragment two or three times until it ceases to decrepitate after desiccation. Then remove it to the aluminum tray (Fig. 20), cover it with an H.P., and observe the pyrochrome. The white sublimate of *volatile* metals is here obtained on the steel forceps, with a little of that of some *volatilizable* metals, if the latter are heated long in O.P. Materially,

* Vide Paragraph (240).

however, these may be thus separated. Now place a small charcoal mortar under the essay on the plate, and again heat in O.P.; by this process the volatilizable metals are separated, as vapour, after which the residue may be determined in $\ddot{H}\ddot{B}$ or $\ddot{H}\ddot{B}$ as is expedient.

With regard to Classes (3) and (4), a fragment the size of a pea should be covered with a candle H.P. on aluminum plate; the pyrochrome observed, a drop of water put on the hot essay, and that evaporated with H.P. again; another drop of water will, if any sulphuric or phosphoric acid is contained, leave a dark stain on the plate in cooling, which should be rapidly washed off, as it can only be eradicated with moist emery cloth. The essay is then tested in the E.P.* to see if it contains lime, strontia, lithia, magnesia, &c.; baryta and potash will have been previously indicated, if present without soda, by the O.P. pyrochrome. The fragment is then crushed, and a smaller one, the size of half a pin's head, applied to an $\ddot{H}\ddot{B}$ glass, and treated with a strong O.P.; if unaltered, it must be crushed to fine paste, and again thus treated. In this operation will be determined (by the indications given under separate heads), whether the essay is chiefly composed of alkaline earths, or chiefly of silica and alumina, with a slight quantity of the former earths; alkalies, especially potash, are generally detected in minute quantity in earthy minerals supposed to be quite free from them, as also phosphoric acid. They are here determined by the instructions given. The yellow alteration of the $\ddot{H}\ddot{B}$ pyrochrome betrays the slightest trace of soda; vesiculation determines that of potash. If the essay is white, confirmation of the presence of alumina, &c., may be made by cobalt and manganese solutions.

(r). *Manipulation to obtain the Base of Arsenides, &c.*—This is generally an easy but tedious operation, seldom, if ever, absolutely necessary in qualitative analysis, and in that case best performed with the table pyrogene. The smaller the essay the more rapid the operation, but too small a fragment is in danger of being completely volatilized on the charcoal mortar. If the mouth pyrogene is used, a piece the size of a pin's head is sufficient, but with a table pyrogene three or four times as much as that may be used. The essay is first treated with a strong O.P. on aluminum plate *per se*, the sublimes noted and tested with O.P., &c. It is then subjected to precisely similar treatment, with a charcoal mortar on the plate, when it generally fuses to a black (if antimony is present) or grey indistinguishable ball. This ball is then placed on the clean aluminum plate along with a piece of $\ddot{H}\ddot{B}$ not larger than itself, to hold it in one position, and treated with a strong O.P. A drop or two of water is placed above it while hot, and if that does not detach it from the plate, the water is boiled by a spirit lamp underneath, which happens in a single second,

* Vide Paragraph (141).

and never fails to detach the essay. This now has a flat side which has been resting against the plate, the rest being round. The flat side always contains the basic metal in greater or less quantity. If it is required to obtain this pure, more $\ddot{H}\ddot{B}$ must be added above and the operation repeated. Copper may thus be obtained from its pyrites in a few minutes. All its other ores are thus manipulated much more quickly, the iron in the former taking time to slag off.

(s). *Manipulation to determine the Base in Arsenides, &c.*—Procedure as above, except that of course it is not here required to go farther than ascertaining from the color and appearance, &c., of the flat side of the ball what the basic metal is: when the operator confirms the indication by treating the small essay in a momentary O.P. at the bottom of an $\ddot{H}\ddot{B}$ bead on platinum wire, by which means a trace of silver in common *galena* is at once detected.*

(t). *Manipulation in the Process of Lead Fuming.*—It is provoking to seemingly go over the same ground in the course of these explanations, but it will be soon observed by the attentive reader that when this ground, opened up for the first time, offers new, unexpected, and evidently important indications, it will not do, consistently with the plan of this work, to attempt to incorporate a record of the new revelations, although appearing in the same groove of analysis, with the old. Such a system is in fact impossible here, without doing injustice either to the former or latter facts recorded, and I therefore submit that, subject to the charge of repetition, I offer to the student the advantage of foregoing the labour I have incurred, so that he will generally find complete instructions as to procedure in any particular course of analysis without the trouble and annoyance of being referred back (or forwards) to other pages.

PURE LEAD (*probir blei*) possesses the inestimable, and, so far as I at present know, the unique advantages, as a reagent, of first forming a fusible or semifusible *alloy* (the term is used advisedly) with every metal, or oxide of malleable metal (for that is apparently reduced by the fusion), supported on charcoal over aluminum plate before O.P.; and second, of fuming or pyroxidizing under the same conditions, when its fume or pyroxide carries up with it in sublimation that of almost every other metal, including even gold and platinum; so that the presence of those in the combined fume may be easily recognized by testing with $\ddot{H}\ddot{B}$, $\ddot{H}\ddot{P}$, or by methods to be described. Lead is supposed to merely mechanically dissolve platinum, for instance, when this is fused pyrologically with that. But surely it is a veritable alloy, when, in white heat, part of one metal is sublimated with the other; and the other, notwithstanding the great heat, can still be proved to contain part of that in the residue?

A paste of the crushed mineral, or oxide made with water, is plastered in

* Paragraph (243, c).

the hole of a keyhole mortar,* a few specks of test lead (*probir blei*) laid upon that, and some more of the essay paste plastered over all with a penknife. If the essay be a metal or alloy, a piece of it is merely laid alongside the lead. The mortar, thus charged, is placed on the ledge of an aluminum fuming plate,† which has been previously well cleaned and polished, held in the muffed or (θ) forceps.‡ A strong O.P. is now directed upon the mass in the mortar, which is kept just *within* the point of the blue pyrocone, so that the pyrochrome (which is invariably produced) streams over the mortar and impinges against the aluminum plate. It will be observed that wherever this pyrochrome touches the plate, the characteristic sublimate of the burned metal is deposited; from which fact it would certainly seem as though the former consisted of infinitely small particles of the latter in a state of incandescence, and yet this cannot be the case with regard to some substances, as, for instance, lime, which is quite infusible before the pyrocone, and yet can be made, by merely touching the wick of a pyrological candle (while a pyrocone is being produced from that) with a fragment in a caustic state,§ to generate a copious and beautiful red-orange pyrochrome for half an hour without causing any loss of weight in the fragment.

After blowing for more or less time, as the substance combined with the lead is less or more fusible, the fume or sublimate is observed to be spread in circular form on the long side of the aluminum plate at the back and round the essay in the shape of a halo, which seems, whatever other colors it possesses, to be invariably terminated by a white, or nearly white, border. This white border is scraped gently and carefully,‡ off with a smooth-edged penknife, so that the aluminum be not scratched, and placed on an agate slab in two portions, one of which is to be tried in an $\ddot{H}\ddot{B}$ glass in the ordinary manner under O.P.; the other in an $\ddot{H}\ddot{P}$ glass. Strange to say, some oxide of the most (hitherto considered) stable metals as gold, platinum, cobalt (for silver is known, in Germany at any rate, to be volatilizable), will be found in this white border in greater quantity than nearer the essay. The behaviour of different sublimate will be found under the separate heads, but it may be here mentioned that the (apparently) *highest* oxides are almost invariably found in this white border, and lower ones, if any besides that of lead, in the inner or colored rings. After all required for analysis has been scraped from the sublimate, a small clean paint-brush, holding a drop of distilled water, should be applied to the most highly colored part, and that, well mixed, thus transferred to white paper in a small square of color opposite a note of its constituent parts: thus, "lead + silver \square ," or "lead + cobalt oxide \square ." Pure lead fume alone affords, after some O.P., a clear, colorless glass, both in $\ddot{H}\ddot{B}$ and $\ddot{H}\ddot{P}$, which is not altered by an H.P. Every oxidal

* Paragraph (101).

† Paragraph (98).

‡ Fig. 37.

§ Paragraph (129, i).

addition to the first, and most to the second kind of glass, affords characteristic reactions to be found under the separate heads. Another fact of (in my mind) immense value in this simple process is the combination of the volatilized oxides with the lead fumes in *definite proportions*, whatever be those in which they are present in the essay. Thus the fume of lead, fused with cobalt oxide containing only 5 per cent. of nickel oxide, gives an $\bar{H}\bar{P}$ glass of a much paler and indeed different tint to that of the plumbocobalt fume glass. While the latter in $\bar{H}\bar{B}$ produces opaque lavender-blue, the former yields opaque slate color. When any metallic ball (as they often do) springs red hot from the charcoal mortar on to the aluminum, the under, flat, side is invariably found with ellipsoidal cavities, evidently proceeding from the escape of gas upwards, i. e. from the aluminum plate.

(u). When the essay is accompanied by a quantity of silica or silicious matter from which it is in too small proportion to be freed by reduction with a flux previous to examination, as, e. g. in very poor gold quartz, plumbic silicates will be formed, of the probable composition of which the following table, taken from 'Percy's Metallurgy,'* gives a good idea :

	Quantity operated on in Grains.		Composition of Product per Cent.	
	Red Lead.	Silica.	Protoxide of Lead.	Silica.
I. 3PbO SiO_2	2320	300	88.1	11.9
II. 2PbO SiO_2	2320	450	82.6	17.4
III. 3PbO 2SiO_2	2320	600	72.2	20.8
IV. PbO SiO_2	2320	900	71.1	28.9
V. 2PbO 3SiO_2	2320	1350	62.2	37.8
VI. PbO 2SiO_2	700	580	55.2	44.8
VII. PbO 3SiO_2	470	550	45.1	54.9
VIII. PbO 4SiO_2	400	620	38.1	61.9
IX. PbO 12SiO_2	350	1740	13.9	83.1

"Nos. I., II., III., and IV. melted easily at comparatively low temperatures, and the products were perfectly vitreous. No. V. required a rather high temperature for its fusion, but the product was also perfectly vitreous. No. VI., at a high temperature, fritted into a compact, white, opaque, porcelain-like mass, which, on being remelted at a higher temperature, became a perfect glass. No. VII. could not be melted into glass, but formed a compact, homogeneous, porcelain-like mass. No. VIII. yielded a white compact mass with only a few cavities in it. No. IX. fritted into a white porous mass."

The above seems to be a citation of experiments by Dr. Beck. It will be observed that where the proportion of silica exceeds that of plumbic oxide, the result could not be completely vitrified.

* Page 29, Metallurgy of Lead.

When a metal, disseminated in an extremely fine state of division in a siliceous matrix, cannot be collected by reduction from that on account of its very trifling proportion, it can, nevertheless, if its oxide afford a chromatic glass, be detected by lead fuming, by adding sufficient lead to form a vitreous plumbic silicate, in the shape of a yellow transparent bead: the proportion of lead to silica being, presumptively, about that of VI. in the above-quoted table.

A very minute proportion of less oxidizable metals, as gold or copper, will now be obtained, reduced to a ball or balls in this bead; but if the proportion is even too minute for that result, the bead is to be crushed in the (α) forceps on the agate slab and again fused with test lead in a mortar on aluminum, when a portion of the scraped-off sublimate will certainly (if any metal be present) afford indications in $\ddot{H}\ddot{B}$ or $\ddot{H}\ddot{P}$. Borax should not be added, as lead then seems to combine in the shape of a black, or nearly black, suboxide, and the plum-boracic silicate—a dark slaggy mass—obstinately resists all attempts at sublimation. Vitrified plumbic silicate, alone, is wonderfully unvolatilizable; and if other metallic oxides are present, these, as, for instance, of gold or copper, may be observed in such a bead, in the form of a ruby-red or brick-red suffusion, as the case is.

(v). *Manipulation in obtaining "Absorption Bands" in Glasses.*—Although spectrum analysis, as at present explained, can scarcely be said to come within the scope of practical application to these methods, a cheap and portable spectrum lorgnette (containing three or five prisms) may be usefully employed in detecting some rare substances—especially didymia, uranic oxide, and erbia—as follows:

The essay-glass (except for didymia, which itself forms a clear ball in $\ddot{H}\ddot{B}$) is made of a calciborate ball,* about the size of a large pin's head (extracted by boiling water), which seems to afford a bandless spectrum, thus: The ball is taken between the points of the (ϵ) forceps, and held there by slipping up the wire band which keeps the legs together. The forceps, having the ball between its legs, is placed with its hilt inserted in the leaves of a thick, large book placed on a table with the back towards the operator, so that the forceps stands upright, and the ball (or glass) may be slanted towards or from him, as may transmit the greatest amount of light from a window, open if possible in front. The ball, having been thus observed to afford a spectrum without bands, is now removed from the forceps and treated in $\ddot{H}\ddot{B}$, so that a speck or two of didymic oxide, for instance, is taken up and dissolved in the ball under a strong O.P., when, if the oxide is at all pure, that becomes pinkish; it is again extracted by boiling water, and placed as before between the points of the forceps' legs. On

* Paragraph (65).

the application now of the spectroscope, the thick didymium band to the right (or green side) of D, and the two thinner bands on either side of Eb, are distinctly visible. "Pure" oxide of cerium, or powder of *cerite*, will also thus show these bands; though not, of course, so strongly. Erbic oxide, thus examined, gives *one* thick line on the red side of Eb in "the green," which, in a saturated solution, fills the whole space between E and Eb; yttric, a fainter one in the same position (probably due to erbia). These last are very interesting; not having (apparently) been observed before. They cannot be due to the possible presence of didymia, because, in that case, the *thick* band, near D, would be surely visible.* Spectroscopists have adopted, in their descriptions, the termination "um" to the names of substances, on the assumption that most spectra are afforded through metallic or elementary agency, but where an oxide has been used it does not seem proper to ascribe the spectrum to a metal: moreover, the result of these investigations seems to show that no spectrum is obtained without the probable presence of oxygen, chlorine, or other non-metallic agency.†

(w). *Manipulation in obtaining Colored Spectral Lines.*—The field of a small spectroscope is so limited that minuteness, and therefore extreme accuracy of determination, is not to be expected here; but, on the other hand, to make up for this defect, the very want of dispersive power in the small prisms used, causes *the whole* of the sometimes numerous lines of the spectrum to flash simultaneously on the retina; whereas, with a large and powerful spectroscope, only a portion could be observed at a time.

SYSTEMATIC QUALITATIVE ANALYSIS.

(130). *Æsthetic Examination*‡ of *Natural Inorganic Substances* (artificial combinations, as alloys, will be treated afterwards).—The principal object of this preliminary process is to enable the operator to *classify* his subjects for further examination. If he neglect, or erroneously make this classification, he will probably find some hours of valuable time wasted, and possibly a valuable subject or mineral lost, of which he can procure no more, by having proceeded on the wrong track. Of itself, this superficial examination is almost worthless; for although many years of practice enable a man in most cases to recognize

* *Vide* Paragraph (229).

† *Vide* the article on Copper, Paragraph (258).

‡ This rather pedantic term is used for want of a better. By it is intended to be implied the result derived from the mere sight, touch, scrape, and sometimes smell or taste, of an inorganic substance.

thus the minerals of *his own locality*, or even perhaps county, such knowledge utterly fails when applied to the identification of substances similarly named as minerals, or nearly identical in chemical composition, from abroad. The late Mr. Garby, of Redruth, who did not pretend to chemical knowledge, was considered—as indeed he was—one of the best practical mineralogists in Cornwall, and I well remember his bringing from some distance, to show me, in the year 1860, a large, black, heavy, amorphous specimen of *argentite*, which he said he had lately received from Chili. Not having then learned the use of the blowpipe, I tried a nitric hydrate solution of this ore with hydric chloride, and failed to get a precipitate, but obtained a “deep blue” by adding ammonia to it. Mr. Garby was very indignant when I said it was a copper, not a silver ore; but wrote me next day, saying it was a specimen of “*Redruthite*,” which he had brought by mistake, having taken it out of the wrong drawer of his cabinet.

(131). The following seems a convenient æsthetic classification :

CLASS (a). Substances having *metallic lustre*.

Native Metals.—(a) white, (b) yellow, (c) red. Types: (a) native *silver*, (b) *gold*, (c) *copper*.

Minerals.—(d) yellowish-white, (e) whitish-yellow, (f) whitish-red, (g) bluish-black. Types: (d) *Mispickel*; *Pyrite*; (e) *Chalcopyrite*, (f) *Nicolite*, (g) *Galena*.

CLASS (β). Substances having *vitreo-metallic lustre*.

Minerals.—Types: (a) *Mica*, (b) *Talc*, (c) *Graphite*.

CLASS (γ). Substances having *vitreous lustre*.

Minerals.—(a) transparent, (b) white, (c) colored, (d) black. Types: (a) *Diamond*; *Rock crystal*; (b) *opaque Quartz*; *Sassoline*; (c) *Zircon*, (d) *Tourmaline* (black variety).

CLASS (δ). *Lustreless* substances.

Minerals.—(a) white, (b) colored, (c) black. Types: (a) pure *Marble*, (b) *Hematite*, (c) *Anthraconite*.

Speaking generally (a) class is treated on *aluminum plate*, with O.P. on a charcoal mortar (if reducing effects are required), and then in $\ddot{H}\ddot{P}$ and $\ddot{H}\ddot{B}$ for chromatic and *initial* reactions. For *sublimates*, they can be ground with ferrisquioxide and water, and roasted on a platinum tray.*

Classes (β), (γ), and (δ) can all be first tried directly in $\ddot{H}\ddot{B}$, and the results boiled, &c., according to directions; (δ) (c), however, which often contain nitrogen, should be tried for that substance in the manner directed. The “streak” and hardness are determined by scratching with the point of a knife, and observing the powder displaced; but if this is done with the view of comparison, the point

* *Vide* Directions.

of the knife must be looked to and sharpened, as it is generally *turned* by the first hard mineral, and then, of course, would not afford a fair test of the hardness of a second.

SYSTEMATIC QUALITATIVE ANALYSIS.—PART I.

A.—APPEARANCE AND REACTIONS PER SE.

(132).

I.—*Æsthetic Examination.*

- a. The substance has microscopically a metallic lustre (Class *a*).
- b. The substance has microscopically an earthy or stony appearance (Class *δ*).
- c. The substance has microscopically the appearance of a salt (Class *δ*).
- d. The substance is waxy, hard, with (*d'*) metallic streak, or (*d''*) non-metallic.
- e. The substance is waxy, soft, with (*e'*) metallic streak, or (*e*) non-metallic.
- f. The substance is heavy.
- g. The substance is light.
- h. The substance is crystalline (Class *γ*), colored (*h'*), or transparent (*h''*).

(133).

II.—*Tubular Examination.*

1. Crush, if obtainable, a crystal of the substance to the finest possible powder; first in the (*a*) forceps, and then between the two polished agates. The method of heating in platinum forceps is apt to lead to incorrect conclusions, and is, for this examination, a waste of time.

2. Place some of the powder in a small test tube, and heat over a spirit lamp, with the first finger closing the mouth of the tube, and two slips of test paper, one blue, the other red, hanging down on opposite inner sides.

- a. Drops of water condense in the neck of the tube.
- b. A white sublimate condenses, or (*b'*) a metallic ditto.
- c. On raising the finger an organic smell is perceived.
- c' On raising the finger a sulphurous smell is perceived.
- c'' On raising the finger a garlic smell is perceived.
- c''' On raising the finger a horseradish smell is perceived.
- d. A white smoke fills the closed tube.
- e. A colored smoke fills the closed tube.
- f. The red paper has blue spots on it.
- g. The blue paper has red spots on it.

(134). III.—*Examination in the Hydrocarbonous Pyrocone of a Pyrological Candle.*

Coal gas will not answer the purpose ; jet β to be used.

The powdered substance is to be mixed with a spatula (one of platinum is best) on agate or a glass slab to a stiff paste, with distilled water, and taken up in the form of a roundish ball on a loop of thickish platinum wire, and thus held in the centre of a pure H.P., Fig. 15.

- a. The white substance turns black or grey-black.
- b. The black mass shows botryoidal swellings, or (*b*) crystalline facets.
- c. The substance remains perfectly white, or (*c*) its original color.
- d. The substance changes (or *d* not) color on being quenched while hot with pure water, and the steam gives off a smell of rotten eggs.
- e. The substance fuses on the surface.
- f. The substance fuses altogether.
- g. The substance has a black spot next the base of the pyrocone.
- h. The substance has a green spot next the base of the pyrocone.
- i. The fused substance is clear hot, opaque white on cooling.
- j. The substance collects soot, and glows after being taken out.
- k. Cobalt solution applied to the hot white mass turns it blue.
- l. Cobalt solution applied to the hot white mass turns it pink.
- m. Cobalt solution applied to the hot white mass turns it peach color.
- n. Cobalt solution applied to the hot white mass turns it light green.
- o. Cobalt solution applied to the hot white mass turns it dark green.
- p. Cobalt solution applied to the hot white mass turns it purple.
- q. The substance held nearer the point of the H.P., and moistened with water, after long treatment, affords only an orange pyrochrome.
- r. The substance held nearer the point of the H.P., and moistened with water, after long treatment, affords only a violet pyrochrome.
- s. The substance held nearer the point of the H.P., and moistened with water, after long treatment, affords only a violet-red pyrochrome.
- t. The substance held nearer the point of the H.P., and moistened with water, after long treatment, affords only a green pyrochrome.
- u. The substance held nearer the point of the H.P., and moistened with water, after long treatment, affords only a blue pyrochrome.
- v. The substance held nearer the point H.P., and moistened with water, after long treatment, affords only a rose pyrochrome.
- w. The substance moistened with a drop of sulphate of copper affords only a blue pyrochrome.

N.B.—A coal-gas pyrocone answers for these, from *q* to *w*. The pyrochrome of substances which *fuse* (as *Barite*) may be taken with O.P.

(135). IV.—*Examination in the Oxyhydrogen Pyrocone.*

- a. The substance glows with intense white light.
- b. The substance glows with a yellow light.
- c. Applied *after* cobalt solution, the mass remains blue.
- d. Applied *after* cobalt solution, the mass remains pink.
- e. Applied *after* cobalt solution, the mass remains green.
- f. Applied *after* cobalt solution, the mass remains grey-black.

(136). V.—*Examination on the Platinum Tray.* (Class (a), d, e, f.)

- 1. To be intimately mixed with lime, and treated with O.P. *on the back only*.
 - a. The sublimate on steel forceps leg is white.
 - b. The sublimate on steel forceps leg is brown-orange.
 - c. The sublimate on steel forceps leg is lemon yellow.
 - d. The sublimate when scraped forms metallic globules.
- 2. The substance giving a white sublimate is mixed with a little rust, and heated.
 - e. The sublimate on steel forceps leg is still white.
 - f. The sublimate on steel forceps leg is still brown-orange.
 - g. The sublimate on steel forceps leg is lemon yellow.
 - h. The substance is disposed in leopard-like spots.
- 3. The substance is mixed into a paste with sulphur and pure water, or if a fluid, is poured on the tray with sulphur in it.
 - i. The forceps leg viewed perpendicularly has a white sublimate.
 - j. The forceps plunged hot into water turns black.

(137). VI.—*Examination on the Charcoal Mortar.* (Class (a), a, b, c.)

Mix the substance with borax and soda; if difficultly fusible, with potassic cyanide, and treat with H.P.

- a. The substance fuses to a metallic globule.
- b. The *back* of the globule is bluish-grey.
- c. The *back* of the globule is red.
- d. The *back* of the globule is white.
- e. The *back* of the globule is yellow.
- f. The substance will not fuse to a metallic globule.

(138). VII.—*Examination on Aluminum Plate.** (Class a.)

Wrap the substance in paper, and treat with direct O.P.

All the experiments of V. and VI. may be better made on this support, as aluminum seems to have no affinity for other metals, with the exception of copper, and for that only when pure, while arsenides, antimonides, &c., may be fused on it without the least fear of corrosion. Unlike platinum, however, it attracts sublimates before they can reach the steel leg of the forceps, so that a larger quantity of the subject of analysis is required. The steel legs of the forceps should be burnished before use with the smooth back of a table-knife, the aluminum tray having been smoothed with the (γ) forceps under linen or calico, and well scrubbed with moist emery paper.

a. The white substance, directly treated with O.P., leaves a dark stain on the plate after being washed with a few drops of water, and (α') a *white metallic stain*.

b. Treated with O.P. alongside of a small fragment of fused carbonate of soda, and a drop of water applied, a disgusting smell is evolved, and a dense black precipitate produced without effervescence.

c. With the above treatment, a slight smell and dark precipitate is produced, with much effervescence on adding the water.

d. The metallic glancing fragment treated directly with O.P. produces a deep black-brown sublimate immediately round it.

e. A brown sublimate appears a little above the subject, which in a long P.P. becomes yellow.

f. After long O.P. the metallic glancing substance produces fine green hairs of oxide.

(139). An *aluminum spoon* † is very useful for noting pyrochromatic effects by applying O.P. on the edge of a fragment, also for O.P. effects *after* the application of cobalt or manganese solutions, as the heat being so rapidly conveyed away from the bottom of the fragment renders the top (where O.P. is applied) hotter; this fact can be proved by experiment.‡ *Silver foil* is used by placing the substance, previously fused with soda on charcoal upon it, with a drop of water, when the presence of sulphur or sulphuric acid is indicated by a black or brown stain; but inasmuch as similar effects can be produced as above detailed on aluminum plate *directly*, it seems superseded in convenience and rapidity of operation by the latter.

* No substance containing *chlorine* should be heated on this support.

† *Vide* Paragraph (93).

‡ *Vide* Paragraph (129, d).

(140).

B.—REACTIONS IN THE FLUXES.

In works on the blowpipe, the terms "bead" and "glass" are used indiscriminately, to denote the portion of flux fused on platinum wire rings, upon which the subject of analysis or essay (and I may state here, that I use the word "essay" in speaking of a *qualitative*, and "assay," of a *quantitative* analysis) is taken. I have, however, drawn the following distinction, which is necessary, as I have found in many cases a modified shape of the flux taken up to be a great improvement. The word "bead" I apply as it is at present used, to the largest amount of flux it is possible to fuse on a platinum wire ring of a given diameter, and which generally assumes the shape of an ellipsoid. The word "glass" I apply to a much smaller quantity of flux, which, when fused, lies with two nearly *plane* surfaces, and a nearly circular edge bounded by the ring of the wire, to the thickness of which only it corresponds. A "glass," in fact, is an eye-glass in miniature; and this form possesses the following advantages over the "bead": (*a*) The essay can be heated far more strongly and continuously, as there is much less matter to protect it, or to enable it to move or swim round, out of the line of fire. (*β*) It is made (especially as regards H_2B) in *quarter the time*. (*γ*) It is unrolled more easily from the wire, and its flat shape renders it more easily examined in a lens or microscope. On the other hand, a "glass" will not do for quantitative analysis or for vesiculation. The ring of the platinum wire should be made nearly double the diameter of that supporting the bead, i. e. on the very base of the (*δ*) forceps, Fig. 38; and the part where it joins should be kept upwards. Take up the essay on the other or *off* side, and notice if bubbles come *through* the glass or not. When the essay adheres to the platinum wire, unroll the wire from the glass; re-ring the wire, and take up the glass again, so that the essay part does not touch the wire, with the latter, while red hot. The *size* of the bead or glass must be proportioned to that of the essay; a mere speck of that, for instance, would require a bead not larger than a pin's head. A *ringed bead* denotes the case when the small quantity of flux in a glass collects into a small bead and hangs from the large ring. An essay can be more strongly heated under these conditions in O.P. than in any other situation.

VIII.—*Examination in Phosphoric Acid.*

1.—Take up about 2 mgrs. of the powdered substance on one side of the hot bead, and apply O.P. to the *other* side.

a. Effervescence, or (*a'*) no effervescence, ensues; or (*a''*) effervescence with color.

- b. The substance is difficultly soluble.
- c. The insoluble part appears like half melted snow.
- d. The insoluble part appears like pieces of fat.
- e. The glass is yellow hot, but colorless cold.
- f. The glass is colorless hot, but yellow on cooling.
- g. The glass is achromatic hot and cold, but very vitreous.
- h. The glass is blue hot, pink cold.
- i. The glass is green hot, dirty green cold.
- j. The glass is pink hot, bright green cold.
- k. The glass is yellow hot, green cold.
- l. The glass is yellow and creamy hot and cold.
- m. The glass is dim and dirty, but colorless hot and cold.
- n. The glass is yellow hot, flesh color cold.
- o. The glass is yellow hot, pale amethyst cold.
- p. The glass is green hot, deep blue cold.
- q. The glass is yellow-green hot, deep amethyst cold.
- r. The glass is yellow hot, pea (yellow) green cold.
- s. The glass is clear hot, yellow cool, cerulean-blue cold.
- t. The glass is red hot, orange cold.

2.—Take up about .2 mgrs. of the powdered substance on the hot bead, retain it for some time in H.P., and treat the other side with P.P.

- a. The glass is intensely yellow hot, and remains topaz yellow.
- b. Fragments begin to form in the clear glass after long blowing.
- c. The creamy O.P. glass (1, l) becomes clear.
- d. The dim O.P. glass (1, m) in half inch P.P. flushes with blue-violet cold.
- e. The (1, q) bead becomes colorless.
- f. The dirty-green O.P. bead (1, i) becomes a bright greenish-blue.
- g. The O.P. bead (1, p) becomes clear and achromatic.
- h. The O.P. bead (1, o) becomes intensely amethyst cold.

3.—Hold the glass in a careful H.P.

- a. The metallic appearance is alloyed with a yellow tinge.
- b. The glass (2, c) held for a second only, is margaritized.*
- c. The bead o (1) is rendered colorless and transparent.
- d. The bead (2, f) becomes brick red and opaque.

4.—Make the glass blue-green by adding 5 per cent. of CuO in a long P.P.

- a. The substance added in a short P.P. turns the glass a brilliant *emerald* green.
- b. The glass turns an *olive*-green.

* I. e. made like a pearl: from *margarita* (Lat.), a pearl.

- 5.—Make the glass (4) green by the addition of fresh $\ddot{\text{H}}\ddot{\text{P}}$ in a short P.P.
- The added substance turns the glass *green-blue*.
 - The added substance turns the glass a perfect blue.
- 6.—Make a glass on *copper* wire by fusing $\ddot{\text{H}}\ddot{\text{P}}$ in the flame of a spirit lamp, and adding to it, while hot, a trace of fused sodic carbonate.
- The substance added and held on the outer surface, or at top of the spirit-lamp flame, gives an intensely *blue* pyrochrome.

(141).

IX.—*Examination in Boric Acid.*

- 1.—The glass must be held, with the joined end of the ring uppermost, in H.P. until all the bubbles are expelled. The substance is then added in about .2 mgr. of a fine powder, or in a speck, and heated directly in O.P.
- The substance effervesces and remains in amorphous fragments.
 - The fragments (observed through the *convex* side of a bead, which acts as an additional lens) are like melting snow.
 - The fragments are like pieces of fat.
 - The fragments are black with a rusty halo.
 - The fragments are green with metallic-looking parts.
 - The substance fuses to a clear glass (fluid).
 - Vesiculated and breathed on, a bead remains clear, or *g'*, like the tarnish of breath on glass.
 - Vesiculated and breathed on, a blue cloud forms over.
 - Vesiculated and breathed on, instantaneous white opalescence follows.
 - The substance effervesces, and congests into small contained sphericles.
 - These sphericles are white and solid looking.
 - These sphericles are oily and diaphanous.
 - The sphericles are semitransparent, red and resin-like.
 - The sphericles are opaque purple-blue.
 - The sphericles are opaque brown, becoming transparent after long O.P.
 - The sphericles are transparent green.
 - The sphericles are opaque green.
 - The whole bead assumes a beautiful opaline color on cooling.
- 2.—The bead and contained ball is treated with H.P.
- Opaque spherospheres, pale buff color, and bulky; and *a'*, opaque green-yellow.
 - The balls (1, *n*) become (*a*) lessened, giving out brick red streaks of an oxide, which will not form balls; and (*β*), the whole ball is changed to violet, and if the H.P. be continued, clings to the

platinum wire, and deposits upon it a white malleable metal, easily disengaged from the platinum by boiling.

3.—Fresh fused boric acid is added under O.P. to the bead and balls.

a. The clear balls become opaque and white; or *a'*, buff color; or *a''*, green-yellow; or *a'''*, brown.

4.—The substance is dissolved as far as possible in the $\text{H}\ddot{\text{B}}$ bead, and the green pyrochrome observed, if it be altered or not, by placing a pure $\text{H}\ddot{\text{B}}$ bead above it.*

a. The green pyrochrome has a tint of orange; or *a'*, becomes wholly orange.

b. The green pyrochrome is quite changed to a *bluish-green*; a much more brilliant color; or *b'*, is slightly increased in intensity.

c. The substance spreads over the bead in creamy streaks with a rose tinge, and (*c'*) without a rose tinge, rendering the bead finally opaque by fresh additions.

d. The substance is invisible or transparent hot, but spreads, on cooling, over the bead as an opaline suffusion, which is brownish by transmitted, bluish by reflected light.

(142).

X.—*Examination with Soda.*

Soda (the bicarbonate fused in a platinum crucible is best) may be added to all the chromatic oxides treated as in IX., when the beads will be colored as in borax.† The *amount* of soda thus taken to produce recognizable colors varies with the nature of the oxide; but this belongs to *quantitative* analysis.

1.—A small fragment of the fused carbonate is melted on the aluminum spoon, and some of the powdered mineral added to it under O.P.

N.B.—It is difficult to detach soda fused on platinum, but not that fused on aluminum.

a. Effervescence ensues.

b. The mass, with water, becomes black, and emits a rotten-egg smell.

c. The mass is tinged with green-blue.

d. The mass smells of ammonia.

e. The mass is tinged reddish-yellow on the edges when cold.

2.—As soda fuses to a ball on aluminum plate or spoon, and the colored reactions might be concealed, add some of the powder; fuse the mass, and add a drop of water while it is still hot, and leave it till the effervescence (which seems to arise from the hot aluminum) has ceased; then fuse the mass in O.P.

a. The mass turns yellow, which is a beautiful salmon color on cooling.

b. The mass turns a dark olive-green.

* *Vide* Fig. 63.

† *Vide* Tables.

N.B.—*Too much* manganese gives only a black or green-black mass; the essay therefore should be added in small traces at first, and ground with the soda and a drop of water between agates.

(143). XI.—*Examination in Barytoborate.*

A glass of boric acid is fused with baryta until it becomes clear. The essay is then added under O.P.

- a. A trace gives the glass a blue-violet (Gr γ) tinge.
- b. A trace gives the glass a nut brown (2 $\cdot\cdot$ 1) tinge.
- c. A trace gives the glass a purple (2 $\cdot\cdot$ 9) tinge.

(144). XII.—*Examination in the Ellychnine Pyrocone (E. P.).*

Platinum jet β to be used. Substances which *fuse* in this small amount of heat should not be examined here unless the cause of fusion has been removed.

The substance is to be first heated in O.P. (held in the roasting hook, unless it is a vitreous silicate, when it is to be held as paste) until it *glows* as much as it is capable of doing, but is *on no account to be fused*. It is then brought in so that the fragment or paste *touches the wick* of the candle, and it is to be held in that position while a pure blue pyrocone *is produced over it*.

- a. The whole pyrocone is tinged "blood red" (H β) or red-violet.
- b. The whole pyrocone is tinged violet-red or (H γ).
- c. The whole pyrocone is tinged pale violet or (H ϵ).
- d. The whole pyrocone is tinged orange-red or (B).
- e. The pyrocone is tinged (B) by a substance which gave a green-yellow (D η) pyrochrome in O.P.

SYSTEMATIC QUALITATIVE ANALYSIS.—PART II.

(145). A.—CONCLUSIONS AND DETERMINATIONS PER SE. *Vide* Paragraph (132).

I.—If the characteristics (*a*) and (*f*) are combined, there can be but little doubt that the substance is an ore or metallic mineral, generally a sulphide or arsenide, of which the prevailing constituent will most probably be detected as in B, VIII. *Graphite* is almost the only substance in nature which has a perfect metallic lustre, and yet contains when quite pure no metallic element. It is at once detected and in a manner estimated *ad valorem* by the admirable method invented by Berzelius of treating the streak made by rubbing the mineral upon fire-clay to O.P., when, if given by graphite and not lead, &c., it will of course rapidly disappear as the carbon is burned, while any *iron* impurity will be left in the state of sesquioxide.

If the characteristics (*b*) and (*e*) are combined, as in *Steatite*, *Meerschaum*, *Meerschaluminite*, &c., the mineral will generally be found to contain a comparatively large proportion of hygroscopic water and organic matter, which the examination by II. will soon settle. It should in any case be referred to B, IX. for determination of the base or bases. Combination of the characteristics (*b*) and (*d*) generally indicate a silicate or aluminate, frequently both together, the peculiar vitreous or quartzose appearance of most silicates is one of the commonest and best of the æsthetic indications. A measure (10 on the glass measuring-tube)* of the powdered mineral containing a larger proportion of silica than of alumina is much *lighter* than one of the converse proportions. The truth will generally be elucidated by III. *a*, *b*; or if that does not afford conclusive evidence in consequence of the presence of ferric oxide, &c., the question can be determined beyond a doubt by VIII. *c*, *d*. A mineral between (*e*) and (*d*), the fracture of which has, through the lens, an appearance like wax, is certain to be a rich (uncrystalline) *limestone*, and even a considerable proportion of combined clay, as in *Lias*, does not obliterate this characteristic indication, of which it seems surprising no notice has been taken. The remaining earths will at once be distinguished by treatment as in IX.

(146). II.—*a*. *Tellurium* is said to also condense in transparent drops, but I have not seen these.

b. The sublimate should be determined by the treatment as in V.

c. Will generally afford the reaction V. *i*.

d. This may be due either to carbon or to some of the anhydrides which give a peculiar blue smoke, as, e.g. phosphoric anhydride. Both it and boric anhydride have a pleasant aromatic smell.

e. A few substances as iodides (purple), nitrous oxide (orange), &c., afford a very high colored smoke when heated, but they require to be in large proportion.

f. An alkaline excess.

g. An acid excess.

(147). III.—*a*. This denotes the absence of any considerable proportion of *lime* or *strontia*. If not perfectly black, the mass should be treated as in *d*.

b. Alumina; *b'* silica. The mass should be referred to *d* if white, as even 6 per cent. of lime will cause the *off* side of the H.P. (next the apex of the cone) to remain white until quenched with water.

c. This indicates pure *lime* or *strontia*. If not perfectly white it may be magnesia. Decide the point by *k*, *l*, and IX. *k*, *l*. If the substance fuses, it is probably baryta. Decide as above. *c'* may be due to Fe_2O_3 . Decide by IX. *q*.

d. If the mass does not become dark by this treatment it indicates about

* Fig. 40.

80 per cent. of *lime*. This smell (H.S.) shows that the substance is a sulphate, and obviates the necessity of treatment with soda.

e. Strontia.

f. Baryta.

g. Shows that the substance is a *Chloride*, the pyrocone is decomposed and chloride of carbon apparently formed. Confirm by VIII. 4, *b*.

h. Shows that the substance is a *fluoride*; fluorine apparently forming an analogous compound to the last named. The best medium for the exhibition of both is lime.

i. The substance is for the most part one of the alkalies, soda, potash, or lithia. Decide the first two by IX. *g*, *h*; and the last by III. *s*.

j. Some of the metallic oxides, as cobalt and nickel, behave in this manner.

k. Lime or strontia; of these the first will, after a short exposure to the atmosphere, turn green, the last brown.

l. Baryta, magnesia, alumina. Determine the first by IV. *f*, the second by IV. *d*, and the third by IV. *e*.

m. Zinc.

n. Lime combined with iron oxide.

o. Lime and cerium oxide.

p. Silica.

q. This shows the presence of water and also carbonic dioxide. A soda salt affords it very strongly at first, but after continued H.P., the orange tint decreases, and slight greenish tinge is observable. Every substance gives the orange pyrochrome in H.P. strongly at first when dipped in distilled water, but this soon passes off, and if the substance is pyrochromatic, the next color begins to show. Decide if due to *soda* by IX.

r. Potash.

s. Lithia or strontia. Decide by IX. *j*.

t. Baryta, cupric oxide; phosphoric, boric, molybdic, and telluric acids. Decide by reference to those heads.

u. Arsenic, antimony, lead, selenium, sulphur, and chloride of copper. Decide by reference to those heads.

v. Lime and cerium. Decide by IX. *l*, *m*.

w. Chlorine or bromine. Decide by reference to those heads.

(148). IV.—*a.* Lime. *b.* Magnesia. Other earths in a *less* degree. *c.* Alumina. *d.* Magnesia. *e.* Zinc and tin oxides. *f.* Lime, baryta, strontia. Decide the first and third by III. *k*; the second by III. *f* and by IX.

(149). V.—Sublimates seem to have no attraction for metallic platinum, but pass up it, and are deposited upon the steel leg of the forceps.

- a. Antimony, arsenic, or mercury, if no *iron* is present.
- b. Arsenic and iron sesquioxide.
- c. Arsenic, iron sesquioxide, and antimony; the latter covering, and thus modifying the tint of the two former, as by *Tetrahedrite*.
- d. Mercury. The reactions (c) and (d) are beautifully exemplified by the sublimate from the ore called *Tetrahedrite* (tahlerz), which is lemon yellow, and when scraped affords mercuric globules.
- e. Antimony.
- f. Arsenic.
- g. Arsenic and antimony.
- h. This occurs when there is a *very* small quantity of arsenic or antimony, with a large proportion of rust.
- i. Chlorine. This may be obtained even from distilled water. Drinking water gives it profusely.
- j. Nitrogen (?). All substances giving off an organic smell when heated afford this reaction. Gunpowder made into a paste with water produces it strongly; but the crystals which form out of the paste when allowed to stand do *not* afford it, which would seem to indicate a *chemical* change of nitrate to carbonate of potash having taken place. *Thick* platinum foil, as is sold in Germany, should be used for this reaction, and it should be long enough to prevent the steel forceps from coming in contact with the flame of the burning sulphur, which may produce black ferric protosulphide.

(150). VI.—a. If not already known of what metal or metals the button is composed, it should be hammered *very* thin, and a small fragment treated as in B, VIII.

- b. Copper, where arsenic or one of the volatile metals is alloyed with it.
- c. Copper, where sulphur is present.
- d. Silver, in a copper alloy.
- e. Gold, in a silver, &c., alloy.

These reactions depend upon the fact that some metals in the order above given have a greater attraction for *heat* than others; the cold (as compared with the other metals in the alloy) metal will therefore be found at the *back*, i. e. towards the apex of the pyrocone. The effects may be equally well produced by the peroxidizing pyrocone, only in this case the mortar must be held upright or perpendicular to it, and the metals in the above order will be found at the back of the ball, which should be heated *just short* of fusion, because if that takes place the ball will spin round, and the different metals alloyed completely again. A few fragments of what is called "gold" lace, cut very

short with scissors, and fused to a (chiefly silver) ball, show this phenomenon admirably.

f. May be Platinum, Iridium, &c. Add *phosphoric* acid to the fragment on the mortar, and heat with strong O.P. Platinum fuses to a ball of the appearance of metallic platinum, but brittle.

(151). VII.—*a.* Sulphur, or sulphuric acid, in an alkaline earth, as in gypsum; *a'*, caustic substances, as lime.

b. A Sulphide. A coal gas H.P. *alone* on soda may produce this.

c. Sulphuric acid.

d. Native Arsenic.

e. Metallic Thallium.

f. A small quantity of Nickel in an arsenide, as in Cobaltine.

Sulphate of Manganese heated on aluminum plate seems to produce on the latter a silvery-white pyrelectric plating, which seems durable under O.P., and is pretty in appearance, but the dark stain or reaction (*a*) cannot be produced on this plating.

B.—CONCLUSIONS FROM FLUX REACTIONS.

(152). VIII.—*a.* This is almost always due to carbonic or sulphuric dioxide—distinguish by VII. *a*—and, by allowing for the phosphoric acid burnt, these gases may be thus quantitatively estimated.* *a''*. Manganic dioxide.

b. Few metallic oxides are very insoluble in phosphoric acid. If, therefore, the difficultly soluble substance is white or colorless, the following procedure should be adopted: Dissolve pure alumina in a phosphoric acid glass until solution *begins* to stop, i. e. when small insoluble fragments *begin* to appear—20 per cent. of aluminum is the limit—then add 2 mgrs. of the powdered substance under a strong O.P., when—

c. Indicates Silica. *d.* Alumina.

e. A large number of substances afford this reaction, as, e.g. the alkalies; the volatile metals, Mercury, Arsenic, Antimony, Bismuth, Iron (in small quantity), Ceric acid, and perhaps some of the earths. These may be thus classed: The volatile oxides, when treated as in (2) *a*, *remain* yellow. The alkalies, though added in any quantity, always give an achromatic bead when cold. The earths are distinguished by the treatment described in III.

f. Nitrogen. No other substance appears to give this reaction, but to pro-

* *Vide* Quantitative Analysis.

duce it the substance (as hydric nitrate) must be added in considerable quantity by the method detailed in (2).

g. Zinc, Tin.

h. Cobalt oxide, when 1 mgr. per cent. is added. 5 mgrs. afford a magnificent "magenta" or violet bead.

i. Cupric oxide; sulphur when added as in (2), and molybdic anhydride in small quantity. Distinguish by *k*, and (3) *d*.

j. Chromic oxide. Its peculiar color while hot distinguishes it from all other greens.

k. Molybdic anhydride and manganic monoxide. The first gives in large quantity a dark emerald green, finer than that afforded by chromic oxide, because more per cent. is dissolved. The second must be carefully prepared from the dioxide before it is added, by the method detailed in III. It cannot then be peroxidized to a pale amethystine bead for some considerable time.

l. Argentic oxide or metallic silver, added in small pieces of very thin foil. The oxide should be kept until dissolved at the *back* of the bead in O.P., or it will be reduced and alloy the platinum wire. It will at first show a very beautiful but very transient shade of pink; the bead being like cream tinged with raspberry juice, and then becomes clear and colorless, but if now suddenly plunged in H.P. and removed, it assumes the exact likeness of a pearl.

m. Auric or Platinic oxide. The glass should be treated as directed in (2) *d*.

n. Ferric oxide. If very faint the glass should be treated with P.P., which brings out the buff color more, or the reaction can be confirmed by treatment with lime in boric acid H.P. A large quantity of this oxide gives the bead a brown-red appearance on cooling, like blood in water.

o. Manganic peroxide. This amethystine tinge is more like that of a pink topaz, and not by any means so fine a shade as that afforded by titanitic anhydride (*q*).

p. Tungstic anhydride. The mineral "*Scheelite*" affords this beautiful reaction quite as well as the pure acid.

q. Titanic anhydride. The mineral "*Rutile*" affords the reaction almost as strongly as the pure acid.

r. Uronic oxide. This fine green is little inferior to that of molybdic acid, though much lighter in color. It is distinguished from that besides, by not being blue cold when added in small quantity.*

s. Nitrogen inorganic. A very large quantity of the substance containing it must be added. If it contains silica the flux must be borax.

t. Nickel.

* The *Spectrum Lorgnette* determines Uranium at once.

(2.)

(153). *a.* Mercury, Arsenic, Antimony, or Bismuth. Determine between these by V.

b. Stannic oxide (?) or Tungstic anhydride. Distinguished by the first being white, the second straw yellow.

c. Silver, of which it requires 20 per cent. to prevent this glass from being transparent and achromatic.

d. Gold. This beautiful reaction affords an excellent illustration both of the operator's skill and of the delicacy of this method, as a hair's-breadth too near the base of the H.P. renders the glass dim as in *m*, while the least shift of position towards the apex of the cone renders it on the other hand diaphanous and achromatic.

e. Titanic anhydride; if there is a considerable quantity in solution the bead will require proportionally long treatment with P.P. to decolorize it.

f. Cupric oxide. 5 per cent. produces this effect.

g. Tungstic anhydride.

h. Manganic dioxide.

(3.)

(154). *a.* Gold. 1 per cent. will produce this effect.

b. Silver.

c. Manganic dioxide. The metallic appearance produced by H.P. must of course be avoided to observe this effect. To this end the glass should be moved slightly about, so as to break the pyrocone and admit a *little* oxygen.

d. Cupric suboxide. Microcosmic salt having copper dissolved in it, requires the addition of metallic tin to produce this reaction.

(4.)

a. The substance contains phosphoric acid.

b. The substance contains chlorine.

(5.)

a. The substance contains sulphuric acid.

b. The substance contains fluorine.

(6.)

a. Chlorine or Bromine. Distinguish by (134, *g*).

(155). IX.—*a.* The effervescence is due to sulphuric acid. The substances at present known to produce this reaction are Silica, Aluminum, Yttria, Erbium,

Stannic oxide, Ferric oxide, Nickel oxide, &c. Distinguish by reference to these heads.

b. Silica ; or Silica + Alumina, and a little alkali ; as in *Albite*, or natural calcic phosphate, as *apatite*. Distinguish by (212, *c*) and (222, *q*).

c. Alumina, aluminic phosphate.

d. Ferric sesquioxide ; but this also forms balls.

e. Nickel oxide.

f. An alkali. Distinguish by (*g*). .

g. Soda. *g'.* Lithia.

h. Potash.

i. Boric acid + chlorine.

j. The effervescence is due to sulphuric or carbonic acid. Distinguish by VII. *a.* Twelve substances are at present known to behave thus, viz. oxides of Strontium, Calcium, Lanthanum, Didymium, Magnesium, Manganese, Cadmium, Barium, Zinc, Copper, Iron, and Cobalt. Distinguish by reference to these heads.

k. Magnesia, until after long O.P., when the ball suddenly becomes clear, and all *hydrates* of the alkaline earths ; as also calcic phosphate. Distinguish by reference to those heads.

l. Anhydrous lime and strontia. These contained balls when extracted by boiling water, are beautifully transparent, highly refractive, and hard enough to scratch glass.

m. The combination of Ceric, Didymic, and Lanthanic oxides found in *Cerite*, and sold under the name of "pure oxide of cerium." They can be separated by extracting the ball from the bead with boiling water, and fusing it in fresh boric acid ; repeating this process until blue transparent fragments (LnO) are observed to separate from the ball by boiling, and the ball itself becomes, instead of brown, a violetish-red color (DiO). The real ceric oxide, which does not appear to form balls, will be found as a flocculent precipitate in the water by which the bead has been boiled, having in this respect a great resemblance to silica decomposed in $\text{H}\ddot{\text{B}}$ from silicate of lime.

n. Copper, and Cobalt oxides. Decide by (2) *b*.

o. Manganic peroxide.

p. Lime colored by iron ; always thus in the state of protoxide.

q. Silicate or phosphate of Lime with Iron, and perhaps also Magnesia, as in *Dolomite*. Detect the latter earth by IV. *b*, *d*.

r. Phosphoric acid : under 1 per cent. (of the bead).

(156). (2).—*a.* These are merely the (1, *m*) balls rendered opaque (that is,

apparently, hydrated) by H.P. They can be made transparent and resin-like again by O.P.

a'. Pure, or nearly pure, oxide of Didymium, but which may contain Lanthanic oxide. Separate these as described in (1, *m*).

b. The ball (α) is due to copper, and thus becomes suboxidized. (β) Suboxide (?) of Cobalt; the white pyroelectrically deposited metal being Cobalt. Of these two oxides (α) becomes orange by boiling in water; (β) remains violet.

(3).—*a*. Magnesia. *a'*. Ceric, &c., oxides. *a''*. Didymic oxide. *a'''*. Manganic oxide.

(4).—*a*. Under 2 per cent. of soda. *a'*. Over 2 per cent. of soda.

b. Cupric suboxide. *b'*. Potash, or Sulphuric acid. Distinguish by X.2, *a*.

c. Silver, or its oxide.

c'. The volatilizable oxides. Distinguish by VII.

d. Chemical, or constitutional water. This is obtained in more or less quantity from every substance, natural or artificial, which is decomposed by H_2 , except the alkalis, which form it, but dissolve it again immediately. A surface of metallic platinum, larger than the bead itself, if the latter is fused on it, also gives rise to this opaline water.

(157). X. (1).—*a*. Presence of a free acid; generally sulphuric.

b. Sulphur; or SO_3 reduced to sulphur in combination.

c. Manganese.

d. Presence of Nitrogen.

e. Ferric sesquioxide.

(2).—*a*. Sulphur. This unknown but beautiful test is quite as delicate as that for Manganese, so well known, and the slightest trace of Sulphur is thus detected in presence of the latter.

b. Manganese (protoxide?).

(158). XI.—*a*. Cobalt oxide.

b. Manganese oxide.

c. A combination of (*a*) and (*b*), i. e. *Asbolane*.

(159). XII.—*a*. Lithia, or its salts.

b. Strontia, or its salts.

c. Potash or Magnesia. Decide by (137, 4), (*b'*).

d. Lime.

e. Lime and Baryta, as in *Barytocalcite*.

(160). DECREPITATION.—This troublesome phenomenon is stated by some mineralogists to have no reference to, and therefore to be no illustration of, the constitutional character of a mineral, since it is not invariable in different specimens of the same mineral; but it struck me that decrepitating minerals are

invariably, or almost invariably, those *crystallizing in rectangular systems* (on the authority of Dana), as the following rather limited list seems to indicate :

Name.	System.	Name.	System.
<i>Anglesite</i>	Prismatic.	<i>Galena</i>	Cubic.
<i>Aragonite</i>	Ditto.	<i>Mendipite</i>	Prismatic.
<i>Barite</i>	Ditto.	20. <i>Margyrite</i>	Ditto.
<i>Bournonite</i>	Ditto.	<i>Polyeras</i>	Ditto.
5. <i>Boulangerite</i>	(?)	<i>Pseudo Malachite</i> ..	Ditto.
<i>Chrysocolla</i>	(?)	<i>Plumbogummite</i>	Reniform.
<i>Calamine</i>	Prismatic.	<i>Stephanite</i>	Prismatic.
<i>Celestite</i>	Ditto.	25. <i>Samarshite</i>	Ditto.
<i>Cheneviscite</i>	(?)	<i>Stolgit</i>	Cubic.
10. <i>Chalcophyllite</i>	Rhombohedral.	<i>Spaniolite</i>	Ditto.
<i>Conichalcite</i>	Reniform.	<i>Turgite</i>	Compact.
<i>Diaspore</i>	Prismatic.	<i>Tyrolite</i>	Prismatic.
<i>Diallogite</i>	Rhombohedral (?)	30. <i>Turquoise</i>	Reniform.
<i>Eulytite</i>	Cubic.	<i>Triphyllite</i>	Prismatic.
15. <i>Erynite</i>	Mammillary.	<i>Vanadinite</i>	Hexagonal (?)
<i>Evansite</i>	Reniform.	<i>Wulfenite</i>	Cubic.
<i>Fluor Spar</i>	Cubic.		

In 33 decrepitating minerals, the only exception is *Vanadinite* (hexagonal, on the authority of Dana), and the two or three reniform cases. It is not always convenient, but always takes time to reduce a mineral to powder, because it decrepitates (the only alternative to losing it given in books on this subject), and I believe the following treatment, which answered admirably in the case of *Diallogite* and *Barite*, to be unknown. *Boil* the fragment in distilled water in a platinum spoon or foil (Fig. 55), or porcelain capsule, till the water is reduced in quantity, evaporated, and fresh water added, so as to cover the fragment, and again boiled. Then hold it on the platinum hook in a candle H.P. ; after that in O.P. It will then stand any amount of heat without decrepitating.

A still more rapid and at least equally effective way of performing this operation, is to cover the fragment with cold distilled water on the ledge of the aluminum plate.* Then direct a powerful O.P. on the top of the fragment through the water, which boils and evaporates round it ; the plate is then to be slanted, so that the water from the cooler part runs round the hot fragment which is kept at the point of the O.P. all the time. If it turns red hot or begins to fuse, its decrepitation is cured ; but if it still shows signs of the latter, fresh water is to be poured over it, and the O.P. resumed as quickly as possible. In this way I cured fragments of *Wulfenite* and *Aragonite*—two of the most obstinate decrepitators. The *rationale* of the process seems due to the fact that, as decrepitation is here assumed to be caused by the obstruction given to the escape of constitutional water, converted to steam, by the rectangular form of

* Paragraph (129, c).

ING CHART.

(DE.)

Oxides of the following Metals and the Metalloids give when treated with.	Atom Weights	(9) PYROCHROME. (a) In O.P. (b) In H.P. (c) In E.P. (d) With H ₂ . On Platinum wire.	(10) LEAD. Fumed on Aluminum plate with Charcoal. (a) In O.P. (b) In H.P.	(11) PLATINUM TRAY. O.P. through. (Steel-legged forceps.)	(12) ALUMINUM FUSING TRAY. (a) On Plate. (b) On Charcoal mortar.	To be distinguished from
1. Alloys .. ..	..	.. ..	Fixed (a).	.. ..	Volatile (a). Volatilizable (b).	.. ..
2. Aluminum ..	27	.. ..	.. ..	.. ..	.. ..	Silica.
3. Antimony ..	122	.. ..	.. ..	.. ..	Sublimate turns black in O.P. (b). Sublimate vanishes in O.P. (a).	Arsenic.
4. Arsenic	75	.. ..	.. ..	.. ..	.. ..	Antimony.
5. Barium	137	Green (b).	.. ..	.. ..	.. ..	Lime.
6. Bismuth	210	.. ..	Brown sublimate. HB glass.	.. ..	Yellow sublimate (b).	Magnesia.
7. Boron	11	Yellow-green (a). With CuO, Blue-green (b).	.. ..	.. ..	.. ..	.. ..
8. Bromine	80	.. ..	.. ..	.. ..	.. ..	.. ..
9. Cadmium	112	.. ..	.. ..	.. ..	Brown sublimate (b).	Lead.
10. Cesium	133	.. ..	.. ..	.. ..	.. ..	.. ..
11. Calcium	40	Red-orange (c).	.. ..	.. ..	.. ..	Silica. Alumina.
12. Carbon	12	Dark purple (b). Orange (a).	.. ..	.. ..	.. ..	Strontia.
13. Cerium	92	.. ..	.. ..	.. ..	.. ..	.. ..
14. Chlorine	35	With CuO. Blue (a).	.. ..	White sublimate on steel.	.. ..	Fe ₂ O ₃ .
15. Chromium ..	52	.. ..	.. ..	.. ..	.. ..	.. ..
63. Zinc	65	.. ..	.. ..	White effloresc. turning brassy.	Orange sublimate (a), O.P.	.. ..
64. Zirconium ..	88	.. ..	.. ..	.. ..	.. ..	.. ..

OBJECTS OF THIS precisely the advantages claimed for the Chart; for, if the operator compares the above Chart with, for instance, Platte's same, or extremely similar reactions in borax, microcosmic salt, &c., of different substances, is repeated over and over again, what is called the "behaviour" (or what are, in fact, uncharacteristic reactions) of an oxide is not given simply from the tabular view; while the alphabetical arrangement of oxides above given, seems to me as necessary for a comparison of the blue flame violet;" but adds, "a very small trace of Soda hinders (verhindert) this reaction." And this is the case of another. But it may be said that Potash is an unfair oxide to select, as there were no really trustworthy name by mere force of turning over pages, and finding it as No. 17 of Plattner's Tables, we perceive that the only, and many other oxides; and its reduction to a metallic magnetic state, which, though but a vague characteristic confirmatory are given.



the crystalline molecules; these, surrounded by boiling water, have time to expand their pores by additional heat, so that the constitutional steam escapes without decrepitation. At any rate, two facts seem certain, (α) that decrepitating minerals belong almost entirely to rectangular crystalline systems; and (β) that a mineral cannot decrepitate when surrounded with water.

FREIBERG QUALITATIVE EXAMPLES.*

Remarks.

(161). This could have been found in one operation, e.g. holding a mass of the paste on a platinum ring in a *good* (pyrological candle) H.P., when a *black* patch (chloride of C?) is formed in front, and the pyrocone tinged with green in rear, which reaction (as the substance belonged to Class γ) denotes barium.† Presence of chlorine confirmed by treatment as in Paragraphs (140), (154). Presence of barium confirmed by treatment in $\text{H}\ddot{\text{B}}$, Paragraphs (141), (155).

1. A white crystalline powder.
 - (a) In B gives off H_2O , and loses its crystalline form.
 - (b) On platinum wire, melts, and tinges the flame green (BaO).
 - (c) Dissolves in borax to a colorless bead, which, when a quantity is present, can be flattened. Pearl white (not crystalline).
 - (d) Melted with soda on C and dug out, gives no S reaction. No reaction for CO_2 with HCl and H_2O .
 - (e) With (KHSO_4) in B got a pale yellow (Cl).

(The substance is *Baric Chloride*.)

(162). *Two* operations will detect this.

(a) A fragment treated with O.P. on an $\text{H}\ddot{\text{B}}$ bead effervesces (either CO_2 or

2. Transparent crystals.
 - (a) In B gives off much H_2O , changes color, and sticks to the glass.
 - (b) On C intumescs, remains out-

* The following account of these experiments, on the right side of each page, was lent to me in 1860, in his university note-book, by the late Mr. W. Hustler, of Rosemerry, Cornwall. He was the pupil of Plattner and Richter, at the Freiberg University. Had he lived, there can be no doubt he would have taken a place among the few Englishmen who have distinguished themselves in this field of research by the contribution of original matter to it. Through his knowledge of this art and of geology, he, quite by himself, discovered a valuable deposit of tin ore (*Cassiterite*, I believe), near Orense, in the north of Spain; and leasing the ground, worked some mines there profitably until his death, a few years since. He first taught me the use of the blowpipe in 1859, and I can never forget him. I have made no alteration whatever in his experiments, except in the symbolical expression of salts, which I have modernized. The letter "B" represents a glass "bulb," or closed test-tube; "C," charcoal. The unknown substances were given to students by Professor Richter.

† *Vide* Paragraph (132, f, h).

SO₂), and finally gives a white opaque ball (MgO).

(b) Another piece heated on Al. plate, and quenched with water, shows that the combined acid is sulphuric.

(163). As in (162), the *clear* ball showing lime instead of magnesia. "Ceric oxide" (containing DiO and LnO) gives a rose tint to O.P., precisely like that of lime; but $\ddot{H}\ddot{B}$ would at once detect the difference. There was probably MnO₂ and KO in this "anhydrous" gypsum; most certainly combined water, as $\ddot{H}\ddot{B}$ would have detected.

(164). *One* operation shows this: Treat a trace of the powder in $\ddot{H}\ddot{B}$ under O.P. The *blue-green* p.c.* and indigo balls show oxide of copper: the green amorphous fragments, Cr₂O₃.

[All mechanical mixtures at once *separate* in $\ddot{H}\ddot{B}$. Chemical combinations are not quite so easily detected.]

(165). Easily detected in *one* operation: Application of a few specks of the powder to $\ddot{H}\ddot{B}$, and treatment with O.P., when MnO₂ forms black vitreous balls, becoming transparent and brown in further O.P.: CoO violet, *lustreless* balls, remaining opaque.

side, glowing with a bright light while hot: moistened with Co solution in OF turns pink. (MgO.)

(c) On Ag. foil, gives S reaction. (Substance is *Magnesium Sulphate*.)

3. A white powder.

(a) In B gives off no H₂O.

(b) On platinum wire, or in forceps, lighted strongly, tinged the flame reddish, and did not melt (CaO).

(c) gave the S reaction.

(Substance is *anhydrous Gypsum*.)

4. A greenish-black powder.

(a) Dissolved in borax gave a pure green color; thought Cu was present, so knocked off the bead, and reduced it on C, when it was red from reduced copper. Got the Cu together, and redissolved the remainder of the bead in more borax, having first pressed it abroad. The reaction in the OF was yellow hot, and yellow-green cold, showing the presence of Cr₂O₃.

(Substance was a mixture of CuO and Cr₂O₃.)

5. A brownish-black powder.

(a) Dissolved in borax gave a beautiful reddish-blue, showing the presence of CoO. The red color, however, indicating the presence of another metal, tried it with soda and saltpetre on Pt. foil, and got the blue color of Mn.

(Substance was CoO and MnO₂.)

* P.c. = Pyrochrome.

(166). Detected in *one* operation. The paste on a Pt. ring in a candle H.P. by No. 2, or (β) jet, is apparently unaltered, giving an orange p.c.; but a drop of water on the hot mass gives steam with a strong rotten-egg smell (HS), and, in O.P. a yellow-green p.c. (BaO). Held then in the E.P.,* the p.c. is a pale orange-red, showing a small quantity of lime.

The cause of the brown color should have been investigated.

(167). There is no potash in *Aluminite*, from which the mineral (*Alumite*) is easily distinguished, when mineral comparisons are required. Mr. Hustler, however, like Von Kobell,† distinguishes the two by the solubility of the former in HCl, which is not allowable in pyrology.

Bristow calls this mineral "*Websterite*," in his admirable "Glossary of Mineralogy."

(168). On a Pt. ring, the substance melting to a clear glass hot, and opaque white cold, shows it to contain at least 25 per cent. of an alkali, while the intense orange p.c. shows that alkali to be soda.

In a candle H.P., with a drop of water, gives a dark grey round patch

6. A brown mineral.

(a) In B decrepitates, giving off little or no H_2O : changes to a grey color.

(b) In pt. forceps, melts, and gives a green color to the OF (pres. of BaO).

(c) Gives no sublimate on C.

(d) With soda on C, greatest part sinks in, but a portion of white remains on the year rings (pres. of CaO).

(e) The remains, dug out of the C and put on a silver plate with H_2O , give reaction for sulphur.

(Mineral is *Barite* with trace of lime.)

7. A white chalky mineral.

(a) In B gives off H_2O , which has an acid reaction. No decided reaction in the forceps: does not melt. No sublimate on C.

(b) With Co soln. in OF becomes blue (Al_2O_3).

(c) With soda, on C, substance remains outside.

(d) The C dug out, wetted on ag. foil, gives S reaction.

(e) It is soluble in HCl.

(Substance is *Aluminite*.)

8. A white compact mineral, like fossilized cocoa-nut "meat."

(a) Does not change in B, and gives off little H_2O .

(b) In the forceps melts easily to a round ball, coloring the OF reddish-yellow (soda).

(c) On C gives no sublimate, but

* Paragraph (144). † 'Bestimmung der Mineralien.' Tenth edition. Munich. 1873. Page vii.

n front (chlorine or fluorine): confirm by adding a trace to $\ddot{\text{H}}$ colored green with CuO .* Basic alumina is detected by the pure blue given with Co solution under O.P.; or by the chocolate or puce color given by a drop of manganese solution.†

melts to a clear bead, opaque when cold, which spreads out, and part sinks into the C.

(d) With Co solution becomes blue (Al_2O_3).

(e) No action for S on ag. foil: no action for CO_2 with HCl dil.: no action in B for Cl, Br, or I, so tried it with P salt in open tube, and got the Fl reaction: also tried it with HSO_4 in porcelain cup on glass, and got a first-rate reaction for Fl, so decide the substance to be fluoride of sodium and aluminum, or *Cryolite*.

(169). In an $\ddot{\text{H}}$ bead under an O.P. a few specks of the powder would give—

(a) Black-blue amorphous particles with creamy yellow streaks spreading from them (tungstic acid).

(b) Black vitreous balls, becoming clear in O.P. (MnO_2).

(c) Rusty amorphous fragments and balls (Fe_2O_3), so that the operator would have much better reason than is given opposite for concluding the mineral to be *Wolframite*. *Vide* "Tungstides."

9. A black mineral, with metallic lustre.

(a) Is not magnetic before roasting, nor after. Decrepitates in B, but gives off no H_2O .

(b) Gives no sublimate on C, and no smell of SO_2 or As.

(c) With borax gives a reddish bead cold, as also with P salt.

(d) Is slightly soluble in HCl , and gives a blue color with K_4FeCy_6 (Fe_2O_3).

(e) Heated with HSO_4 a blue fluid is obtained.

(f) Melts to a slag with soda, and is slightly fusible on the edges.

(Substance is *Wolfram*.)

(170). After the (a) reaction, (b) was scarcely necessary; calomel under O.P. on C sublimes *at once*; corrosive sublimate *fuses first* and then sub-

10. A white crystalline substance.

(a) In B gives off a white vapour, which settles on the sides of the bulb, and turns yellow while hot. In

* *Vide* Paragraph (140, 5, b).

† Paragraph (113, a).

limes. This must therefore have been the latter (HgCl_2).

Such substances are, of course, best determined on aluminum plate, as in (129, *g*).

the forceps gives off a lot of white smoke.

(*b*) On C is melted, and gives off copious white fumes, which settle on the C, and are very volatile.

(*c*) With soda in B, gives off a substance which settles on the side, and forms a mirror: when rubbed forms globules (Hg).

(*d*) With CuO on C gives a beautiful blue flame, striped green, (presence of Cl).

(The substance is, therefore, HgCl , or Cl_2 .)

(171). *Vide* (169), by which procedure the constituents would be detected in *one* operation.

Considering the WO_3 forms 75 per cent. of this mineral, its presence does not obtain sufficient prominence in this essay of Mr. Hustler; it seems merely incidentally brought in, in (*d*).

The distinction between TiO_2 and WO_3 would have been best obtained by fusion of the essay with lead; and treatment of the sublimate in $\ddot{\text{H}}^*$.

11. A substance with metallic glance.

(*a*) In B gives no H_2O , and does not change. In forceps melts slightly on the edges. Gives no sublimate on C.

(*b*) In the OF in borax, gives the Mn reaction, and in RF, reactions for Fe.

(*c*) In P salt OF, gives the Fe reaction, as Mn does not color the bead so strongly in P salt as in borax.

(*d*) In the RF got a red bead, which showed that either TiO_2 or WO_3 was there; but titaniferous Fe does not melt in the forceps: this did, so (The mineral is *Manganese Wolfram*.)

(172). According to Dana's authorities (cited) *Mimetite* has 9 per cent. of plumbic chloride, which should show more than "a trace." There appears also to be in most varieties a consider-

12. The substance is yellow, with a crystalline structure.

(*a*) In B decrepitates and changes color a little, but gives off no H_2O .

(*b*) On C gives a smell of As, and

* Paragraph (247).

able quantity of phosphoric acid, and often lime replacing the PbO. These should have been detected.

Al. plate would, of course, have been better than charcoal as a support for this substance.

(173). An unsatisfactory essay, of which the operator seems aware, as his conclusion expresses doubts.

The "drops" mentioned in (d) indicate the presence of some oxide not determined. I have seen antimony sublime thus on steel, and the white sublimate mentioned in (b) suggests the presence of that metal, or of Bismuth, with considerable certainty.

(174). Could have been easily detected in *one* operation in $\ddot{H}\ddot{B}$, or in $\ddot{H}\ddot{P}$.

The color of the oxide is orange, not yellow.

Uranic glasses (made with any description of flux) are best distinguished from the green of Chromic or Molybdic acid by the *Spectrum Lorgnette*, as in (129, v).

smokes; which settles as a sublimate some distance off, while nearer the assay there is a yellow sublimate of PbO, and a globule of Pb is left behind.

(e) With CuO on C it shows a trace of Cl.

(Arsenate of lead, or *Mimetite*.)

13. Substance is of a grey color, with glassy lustre.

(a) In B it melts, giving off no H_2O .

(b) On C melts, affording first a yellow sublimate of Pb, and outside a thick white one, which is pretty volatile. With $KO\bar{O}$, it is quickly reduced, leaving a globule of lead.

(c) In B with soda gives no smell, and nothing is deposited on the tube.

(d) In the open tube gives off a white sublimate, which, treated before the blowpipe, aggregates into drops of a white or grey color; opaque.

(e) With CuO gives a strong Cl reaction.

(I therefore suppose the substance to be $PbCl$.)

14. The substance is a yellow powder.

(a) In B changes to a liver color, and gives off H_2O . On C no sublimate, and with soda or $KO\bar{O}$, is not reduced to metal, but makes a sort of slag.

(b) In OF in borax, is yellow when cold; in RF, yellow with green tinge.

(c) In OF in P salt the bead is greenish-yellow; in RF emerald green.

(d) The borax bead with zinc on C becomes green.

(Substance is, therefore, oxide of *Uranium*.)

[No remarks are necessary with regard to this determination, which, so far as old methods of analysis go, is very good; but it should have been mentioned that the word "crystalline" indicates phosphoric acid.]

15. A green waxy substance.

(a) In B decrepitates, and gives off no H_2O .

(b) In forceps melts easily, coloring the outer flame blue.

(c) On C melts to a white *crystalline* bead, and with $KO\bar{O}$ gives a bead of lead.

(d) Mixed with CuO in OF on C, gives a strong reaction for chlorine.

(Substance is *Pyromorphite*.)

(175). Detected in *one* operation in $\bar{H}\bar{B}$, and further addition of lime. The color of this oxide (Titanic acid) in $\bar{H}\bar{P}$ (or P salt), is certainly not "violet." It may be called "amethystine," or "purple."

Bristow* says, the name of this mineral is derived from "*rutilus*, signifying *shining red*."

16. A reddish mineral, with metallic glance.

(a) In B does not give off H_2O , and does not decrepitate. In forceps infusible.

(b) On C, gives no sublimate; with soda, melts to a reddish bead.

(c) In borax, in OF, gives the Fe reaction; and in RF the color goes away, or nearly so.

(d) In P salt in OF gives a colorless bead; in RF, a beautiful violet color.

(The mineral is *Rutile*.)

(176). Could have been detected in one operation in $\bar{H}\bar{B}$ with the further addition of soda.

Note to (17) by Mr. Hustler. "N.B.—All the lead earths can be tried by melting in a platinum spoon with $KHSO_4$; in which case Cr_2O_3

17. A yellow earthy-looking substance.

(a) In B changes color a little; on C got a sublimate of Pb; the assay melted, and there was trace of a lighter sublimate in the distance.

(b) To see what was with the lead,

* 'Glossary,' p 327.

separates, and is violet. VO_3 orange-yellow; PO_5 lead will in that case remain a white mass of salt."

(177). All this could have been easily determined in a bead of $\text{H}\ddot{\text{P}}$, in which molybdic acid behaves in the most peculiar and remarkable manner,* but the very striking sublimate of MO_3 could be first obtained on aluminum plate.

The "blue color being *invariably* due to the formation of a lower oxide," seems doubtful. In a glass of $\text{H}\ddot{\text{P}}$, a *small quantity* of MO_3 is blue; a *larger quantity* a beautiful deep-toned green, both reactions under P.P.

The acid solution of *Molybdine* can be azurized by means of pure iron, as well as by zinc.

(178). The reaction (b) was alone sufficient to have determined this mineral. It is best performed on an aluminum spoon.†

There was most probably iron, and

* *Vide Molybdates.*

added a little borax glass to the slag left on the C, and treated to OF, when a green bead was produced. This could only be Cr_2O_3 or VO_3 . To prove which it was, treated some of the original ore to OF in P salt, when it was colored green.

(Substance is *Crocoisite*.)

18. A yellow earthy substance.

(a) In B decrepitates forcibly; gives off H_2O . On C got no sublimate but that of Pb with a few metallic beads of lead.

(b) Then tried it with borax glass, when I got a dirty color, so tried it in a bead of borax, and reduced it on C, when a black bead was produced with some white in it from the lead oxide, which spoke of the presence of MO_3 .

(c) To prove this, dissolved some of the powder in P salt, and got in the OF a green color, which, with the other reaction, proved the presence of MO_3 .

(d) Then dissolved some of the mineral in KHSO_4 diluted with H_2O , and then added a piece of zinc, when I got a blue color from the formation of a lower oxide of the MO_3 .

(The substance is *Molybdanoehre*.)

19. A brown mineral with metallic, or rather resinous, glance.

(a) In B decrepitates feebly; gives off no H_2O .

(b) On C gives a white sublimate

† *Vide Paragraph (93, a).*

perhaps Tantallic acid, in this mineral. *Vide* those heads, for the mode of detection.

which is not volatile, and which, with Co solution, gives a bluish-green color. In the forceps it does not melt; but a white efflorescence comes out upon it.

(c) In OF with soda melts to a slag; but in RF with $\text{K}\text{O}\bar{\text{O}}$ got a bead of white metal which was malleable.

(The substance is *Cassiterite*.)

(179). The intense yellow color of the sublimate while hot, is not mentioned; it is so characteristic of all zinc minerals as to scarcely require the confirmation of Co solution. A little soda afterwards is the best test for the presence of manganese. Best done in an aluminum spoon, or on a plate of that metal.

20. A reddish mineral, with resinous glance.

(a) In B does not decrepitate. On C gives a sublimate which is green on moistening with Co solution.

(b) In forceps infusible. With P salt and borax gave a manganese reaction.

(The substance is *Red Oxide of Zinc*.)

(180). The test in borax, after receiving evidence of the presence of tin, which gives no definite reactions in that flux, was of course for the purpose of detecting copper and iron, and seems to have failed.

The whole could have been detected in one operation in a bead of $\text{H}\bar{\text{B}}$, and the further addition of lime would have shown by the green color of the ball formed, the presence of 1 per cent. of iron protoxide.

The failure to detect copper seems a mere omission; zinc, also, should have been detected.

BRISTOW does not seem to acknowledge the name *Stannite* for *Tin pyrites*.

21. A dull grey semimetallic looking mineral.

(a) In B gives off S, which settles on the tube. In open tube, S burns over the assay; also a white sublimate, which settles on the tube.

(b) On C I got a thick white sublimate which settled close round the assay, and on being wetted with Co solution gave a blue-green color; so there is evidently Sn present. There was no sublimate farther off from the assay.

(c) In borax the white oxide was slowly dissolved to a colorless bead, which was unchanged in the RF on C. In P salt melted slowly to a clear bead, so I only found S and Sn.

(The mineral is *Stannite*.)

(181). This curious mineral gives (or at least, a Freiberg specimen gave) when roasted on aluminum plate, a strong and sickly smell of a bean-field, which I have not hitherto noticed in any other substance.

The reactions opposite are given much more rapidly on the above support than on charcoal.

(182). The only doubtful question here, is to find if there is any *fixed* metallic oxide besides that of iron in the mineral. A bead of $\text{H}\beta$ would do this most rapidly and exactly.

It would be interesting to see if there is not some minute qualitative difference between *Plinian* and common *Mispickel*.

(183). Long roasting on aluminum plate would have detected any nickel, and treatment in $\text{H}\beta$ after that, any cobalt existing as "impurities."

The non-evolution of HS may prevent a mineral from being called *Pyrrhotine*, but cannot prevent it from being a magnetic sulphide of iron.

22. A grey mineral, with metallic glance.

(a) In the B got nothing particular. In open tube a strong smell of SO_2 , with a sublimate of Sb, and some grey drops.

(b) On C got first a sublimate of Sb, then one of Pb, and finally a bead of Cu was left. Did not perceive a smell of As, nor had any color in the tube to indicate its presence. Thus S, Sb, Pb, and Cu are present.

(The mineral is *Bournonita*.)

23. A greyish-white mineral, with metallic glance.

(a) In B gives off a red sublimate with smell of As (AsS), then a mirror of As. In open tube gives off SO_2 and forms a sublimate of As and S.

(b) On C melts to a bead, giving off As and S. The bead is magnetic and has a rough surface.

(c) The roasted mineral in P salt and borax gives the Fe reaction, and nothing else.

(Must be *Mispickel*.)

24. A mineral from Pampelli, Corsica.

(a) In B gives off S. On C melts to a magnetic ball, giving off fumes of SO_2 . In forceps, is with difficulty melted on the edges.

(b) Is slightly magnetic before roasting.

(c) In borax and P salt got only the Fe reaction.

(d) The mineral does not appear

to be a magnetic pyrites, for that gives off HS with HCl, and this does not, but it may be a combination of a magnetic oxide with some sulphide.

(184). The treatment of a few particles of this powder in an $\text{H}\ddot{\text{B}}$ bead under O.P. would have at once shown its nature; the Mn balls being black and vitreous, the cobalt ones violet.* It would *also* have detected any iron, lime, barium, or copper, &c., in the mineral, which the *Asbolane* tried by Mr. Hustler may certainly have contained, for no sufficient means have here been taken to detect them.

(185). No notice is here taken of the lead, copper, and lime, which is often found in *Pitchblende*; but treatment in $\text{H}\ddot{\text{B}}$ would have detected these, and the addition of soda would then have given the peculiar green of UO in H.P., when the absorption bands of the bead or glass thus formed, as seen with a Spectrum Lorgnette (104), would determine the presence of this oxide with absolute certainty.

(186). Nothing calling for remark here. *Alabandine* shows its sulphur when treated directly either in $\text{H}\ddot{\text{B}}$ or

25. A black rotten-looking powder.

(a) In B decrepitates, and yields H_2O . In forceps does not melt.

(b) In borax, OF, got a red-violet color which was not pure, so supposed Mn was there. In the RF, the Mn color left, and a beautiful blue remained alone.

(c) Tried then with soda and salt-petre on Pt. foil, and got Mn reaction. Then with soda on C got a slight trace of S.

(The substance, therefore, is *Erd Cobalt*.)

26. A black mineral, with sub-metallic glance.

(a) Very difficultly melted in forceps. In B gives a sublimate of S. On C does not change or give a sublimate.

(b) In borax, OF, is dissolved with difficulty, and gives an Fe reaction. In RF also an Fe reaction. In P salt, got in OF a yellowish-green colored bead, which changes in RF to a beautiful emerald green. This tells us it is Uranium, and there is only one mineral of this nature—*Uranpecherz*.

27. A black vitreous mineral.

(a) In B a very small sublimate of S. In open tube got a lot of SO_2 .

* *Vide* Paragraph (165).

HB. The *amount* of S would of course be best determined by loss.

Del Rio gives silica as an essential component of this mineral. See Bristow's 'Glossary.'

(187). This is about as rapid detection as could be made of four constituents; but an aluminum plate, OP, would have at once exhibited the Zn, As, and S, while the Fe_2O_3 , and any other fixed residue could have been found in HB.

There does not appear to have been any cadmium in this *Sphalerite*.

(188). The residue, after volatilization of the SbO and SO_2 , might have been more quickly determined to be iron by the magnet, but the operator was right to try for anything else in borax, which however could scarcely have detected very small quantities of anything; but HB would.

(189). The first part of this essay (the elimination of volatilizable oxides)

(b) On C gave no reaction alone, but after roasting, the remainder dissolved in borax, gave a red-violet bead. This color vanished in the RF, so there was nothing there but Mn. There are two Mn minerals combined with S, MnS , and MnS_2 , but the latter gives off more S, and has a *red* streak on porcelain, whereas this has a *green* one.

(The mineral is *Manganblende*.)

28. A mineral, with resinous metallic glance.

(a) In B decrepitates, and gives off some As as suboxide. In open tube gives fumes of AsO_3 and SO_2 , which redden litmus paper.

(b) On C, OF, gives a white sublimate which is yellow while hot, and with Co solution turns green.

(c) In borax gives an Fe reaction; in P salt ditto. So we found Fe, Zn, S, and As. (*Zinc Blende*.)

29. A bluish-black mineral; metallic lustre.

(a) In B got a cherry red sublimate of sulphide of Sb. In open tube SO_2 and SbO.

(b) On C, SbO goes off, and an unmelted mass was left behind with a slight smell of HS. This mass pounded and tried in borax, gave an Fe reaction.

(The mineral is, therefore, *Berthierite*.)

30. A steel grey mineral, with metallic lustre.

is much more rapidly ascertained on aluminum plate than on charcoal, while Cu_2O is easily produced from CuO in an $\text{H}\ddot{\text{B}}$ glass by H.P., without the aid of tin.

Conclusions as to sublimates by means of the different *distances* at which they are deposited from the essay on charcoal, have been proved* to be erroneously formed, as those are regulated by the strength of the superposed blast.

The copper of this mineral is developed most quickly by adding a fragment of soda to the essay on aluminum plate.

(190.) Any nickel would have been rapidly detected by O.P. on aluminum plate, as in *Speiss cobalt* (*Smaltite*), when a green capillary oxide of nickel makes its appearance on the fragment after considerable blowing, or, if in too small quantity for that, certainly in $\text{H}\ddot{\text{B}}$ afterwards.

There seems no attempt here to detect the iron or the trace of bismuth existing in this mineral.

(191.) Ground to a paste with water, and roasted *through* platinum foil, this mineral covers the steel leg of the forceps with a lemon-colored

(a) In B got sublimates of SbS and AsS ; in the open tube, of SbO , SO_2 , and AsO_3 .

(b) On C got a sublimate of Sb, some distance from the assay, and nearer, a sublimate of Zn, moved by Co solution. The As goes off first, then the Sb, then the Zn.

(c) The bead that remained after the Zn had gone off was ground up and roasted, as S is still left in it; the roasting, of course, on charcoal.

(d) I then treated in borax, and found the bead colored green-blue. Knocked off the bead, and reduced on C (without Sn, must blow at least ten minutes). The Cu is then reduced as metal, and falls to the bottom; if nothing more is there, the bead will then be colorless.

(The mineral is *Fahlerz*.)

31. A grey mineral, metallic glance.

(a) In B gave off S, no As. In open tube SO_2 and AsO_3 .

(b) On C fuses to a bead, dark grey, giving off fumes of SO_2 and AsO_3 .

(c) In borax gives Co reaction; tried it on C with borax glass for some time, but could not reduce the Co to get a Ni reaction; so think the mineral is

(CoAs , CoS_2 or *Cobaltine*).

32. A black mineral, with metallic glance.

(a) In B decrepitates, and gives a black sublimate, which may be suboxide

* 'Proceedings Royal Society,' vol. xx.

sublimate, which, when rubbed with a knife, forms metallic balls of Hg; the lemon color is caused by the white antimonious sublimate covering the orange one of $\text{Fe}_2\text{O}_3 + \text{As}$.

It is to be presumed from the conclusion, that Mr. Hustler had detected copper in this mineral.

(192). According to Dana* there is no As in *Stephanite*. The best way to detect a small trace of As in combination, is to heat a small fragment on a ball of gold with H.P., *short of fusing*, i. e. red hot, when AsO_2 sublimes with its garlic odor.

The red color of *Pyrargyrite*, or *Ruby Silver*, is probably due to its possessing a larger proportion of gold, which *all* silver seems to contain, more or less.

(193). This is something like a mixture! The constituents, however, would have been more rapidly detected by roasting on aluminum plate, which would have betrayed S, As, Sb, Bi, and Ni. The Co and Cu could then be easily detected in H_2 . It is remarkable that here, as in (31), an attempt is made to *reduce* the cobalt in order to get a reaction for nickel. Plattner, on the contrary,† advises the

of As or HgS . In open tube got a sublimate of Sb, and a ring of Hg; got also SO_2 and a strong smell of As. The metallic ring shows that the black oxide in the shut tube was formed by Hg, for no other substance would give a ring of metal in the open tube.

(Proceeded no further, but the mineral is evidently *Spaniolite*.)

33. An iron black mineral, with metallic lustre.

(a) In B nothing particular. In open tube, smell of SO_2 and a large deposit of SbO_3 .

(b) On C a trace of AsO_3 , and a sublimate of SbO_3 , which was colored red—brownish near the assay—and a large “korn” of Ag remained behind. Thus we had S, As, Sb, and Ag; so that the mineral can either be dark *Pyrargyrite*, or *Melanglanz*. To find the difference, try the streak on porcelain; the former gives a red streak, the latter a black one.

(*Melanglanz*.)

34. A dark grey powder.

(a) In B nothing notable. In open tube, got SO_2 , As, and trace Sb.

(b) On C a strong smell with fumes of As, and a sublimate of Bi and Sb.

(c) On C with borax glass, got first a strong color of Co, then, after long blowing, a reaction for Ni.

(d) With P salt a weak reaction

* ‘System of Mineralogy.’ 1868. Page 106.

† Vide Pages 302 and 612.

oxidation of, and "slagging off," CoO before that of nickel.

(194). There was evidently a failure here to detect the nickel; the cause of the green coloration of the P salt bead being, apparently, a *post facto* discovery.

The nickel and zinc, however, might have been detected on aluminum plate by O.P.,* and the copper with any silver by $\ddot{H}\ddot{P}$; or a few fine filings applied to a glass of $\ddot{H}\ddot{B}$ under O.P.

(195). Heated on aluminum plate in O.P., this mineral affords a white sublimate which becomes yellowish in O.P. (zinc). A coffee brown efflorescence is observed on the *off* side (MnO_2), and the fragment left is magnetic (iron).

Confirmatory tests— $\ddot{H}\ddot{B}$ with addition of baryta (Mn coloration); and in $\ddot{H}\ddot{P}$ glass a woolly sublimate (Zn).

(196). Could have been detected in one operation; the paste held in H.P. on a platinum ring. The presence of chlorine could then have been confirmed by a $\frac{\ddot{H}\ddot{P}}{CuO}$ glass, but the fact is,

for Cu. So in this mixture there is (S, As, Sb, Bi, Co, Ni, and Cu).

35. An alloy.

(a) On C got a very strong deposit of ZnO, and the metal melted with difficulty to a bead which was rough on the surface.

(b) In borax glass, got an Fe reaction, or only a trace of what might be NiO.

(c) In P salt had a strong reaction for Cu, so I found only Cu, Fe, and Zn; but the bead of P salt was in OF, colored green from the yellow of NiO combined with the blue of CuO, so judge the alloy to be

(*Argentine, or German Silver*).

36. A black mineral, with metallic glance.

(a) Infusible. Is magnetic after roasting in RF. Dissolves with difficulty in HCl with smell of Cl.

(b) In borax gives Mn and Fe reactions. In P salt the same.

(c) On Pt. foil with saltpetre and soda, gives a strong Mn reaction.

(d) With soda on C in RF, gives a faint reaction for Zn, so the mineral must be

(*Franklinite*).

37. A white crystalline salt.

(a) In B gives off H_2O dcpts., and melts; with $KHSO_4$ gives a strong smell of Cl. On Pt. wire colors the flame violet (KO).

(b) A crystal moistened with

* Vide Paragraph (190).

that on merely heating this salt in O.P., a chloric smell is evolved, with the violet pyrochrome of potash.

(197). The student may with advantage compare this essay, done almost altogether in "the wet way," with that of the same mineral before given (22), but to boil a substance in nitric acid until the sulphur is separated is no joke, and at best a long business.

(198). *Vide* (21). Mr. Hustler seems to have succeeded better in detecting iron this time.

It seems strange that the iron reaction in borax was not overpowered by that of copper.

The best mode of detecting all three bases is by treatment with soda on aluminum plate.

(199). Roasting on aluminum plate would have detected the As, and any S or Sb as sublimates; and NiO in green capillary filaments almost simultaneously. The Co and Fe would then have been easily separated by H₂B on O.P.

HSO₄ gives the orange-yellow tinge and peculiar smell of chlorates.

(The substance is, therefore, KClO₃.)

38. A black-grey mineral, with metallic glance.

(a) Gives a strong antimonial smoke, which smells a little of As.

(b) Dissolved in HNO₃ and then found S separate, and on diluting the solution with H₂O, got a precipitate of SbO. On separating this, with HSO₄, got a precipitate of PbSO₄, and finally with ammonia, the blue of Cu.

(The mineral is, therefore, *Bournonite*.)

39. A dark grey mineral, with semimetallic glance.

(a) In B with good heat, got a sublimate of S and nothing else. In open tube a smell of SO₂.

(b) On C melted to a bead pretty easily, giving a white sublimate of SnO₂.

(c) Roasted and tried in borax, gives a reaction for Fe.

(d) In P salt, RF, with tin, got Cu₂O.

(e) With soda and borax, got a bead of imperfectly malleable copper.

(The mineral is *Stannite*.)

40. A pale reddish mineral, with metallic glance.

(a) In B gives off As and forms a mirror. In the open tube AsO₃ in large quantities. On C melts to a grey bead and gives off lots of AsO₃.

(b) In borax, a reaction for Co.

Iron would probably have been detected with soda on aluminum plate under a candle H.P.

Could not see any for Fe, but after a few times treating got the Ni reaction.

(c) Tried for Cu with P salt, but got no reaction. Thus As, Co, and Ni, were found; lots of As, a trace of Co, and much Ni.

(The mineral is, therefore, *Nicolite*.)

It will be observed in the above examples, that a description of the behaviour of some minerals and substances, the most difficult at that time to analyze pyrologically, as, e. g. calcic and magnesian silicates, *Tourmaline*, *Cerite*, cast iron (for the P and S), &c., has been avoided, while some analyses are repeated; but, on the whole, these essays are *most valuable* to the student, showing him how the best workers look for *constituents* in minerals, &c., and are rarely satisfied with mere mineral reactions. Plattner * takes as examples *Adular* and *Azinite*, but the results are not at all satisfactory: for instance, he says, with reference to the former, "the silica seems to be combined with alumina, *because* soluble with difficulty in borax," while in the latter, Al_2O_3 , CaO, and a little MgO, are all left to be detected by "the wet way."

INORGANIC SUBSTANCES IN NATURE.—*Classification*.

(200). We have hitherto considered different modes of analyzing substances by fire; let us now take a general view of the substances—the *vilia corpora*—with which Nature presents us, to operate on. These come to us, naturally, in two grand divisions; (A), metals; and (B), minerals. (A) class is comparatively rare, and presents little interest to the analyzer, as requiring no ingenuity or research to identify it; but two facts concerning this division are worthy of remark: (*a*), that the native metals most generally found—Gold, Silver, and Copper—are precisely those which are most easily deposited electrically, from their solutions; and (*a'*), that no such thing as a perfect *alloy* has been found native. Silver, indeed, has been found in native gold and copper, but only disseminated through it, not alloyed with it. The conclusion from a consideration of these facts seems to be that native metals have not been reduced by heat, but rather deposited electrically.

* Pages 499, 500.

(201). Minerals (B) may be described as petralized, or litholized metals;* and the four great agents used by Nature for effecting this transformation appear to be, (b) oxygen; (b'), sulphur; (b''), arsenic; and (b'''), chlorine. The first and last of these alter the metallic appearance much more than the two others, while it is a curious fact with regard to those, that some metals mineralized by them assume the lustre and color of other metals having a perfectly different character; thus, *Chalcopyrite*, and sometimes even *Pyrite*, have often sufficient resemblance to native gold to mislead the unpractised observer; while *Mispickel* may be found almost as white and lustrous as silver. Of these subdivisions of (B), (b) condition, although apparently the most different from the metallic state, is generally easiest to reduce back to it, and oxygen, moreover, seems in several cases to have been compelled to call in the assistance of carbon in order to mineralize some metals.

(202). Although the mode of investigation which has been called "mineral reactions"† is again deprecated here, as not merely comparatively useless, but absolutely injurious to the progress of pyrological analysis, which may be described as the chemical dissection of minerals, while the former process is more like the quarterings of a butcher than the operations of mineralogical anatomy, it is nevertheless as necessary, or at least as convenient for the pyrologist as for the mineralogist, to have some classification of the subjects he investigates, so as to put his hand more rapidly upon any particular natural or artificial combination of them.

(203). Classification is apparently, as yet, "the lion in the path" of mineralogists; each able writer having adopted his own system of disposing of the "noble beast," who, however, still seems to stalk our scientific streets with savage dissatisfaction. Thus PHILLIPS (1823), not straying very widely from the primeval classification of CRONSTEDT, father of systematic mineralogy, tabulates minerals from *Quartz* to *Cinnabar*. BERZELIUS (1843) gives us an arrangement commencing with Tellurium, and ending with *Topaz*; which he calls "the order of the electro-chemical system." PLATTNER (edit. of 1865) begins with Potassium and ends with Tellurium. DANA, in that magnificent volume which is a library in itself (1868), ranges from *Realgar* to "Oxalate of Lime." DES CLOIZEAUX (1862) adopts the electro-negative element as the classifying unit; and, consequently, gives us a volume (the most important one on the subject ever published) on the silicates, which naturally comprises many of the electro-positive radicles. Finally, VON KOBELL presents us (1873) with

* Silicon, an exception, may yet be discovered, like Aluminum, to be a "metal."

† E.g. "Fusibility on edge," and "decrepitation," &c., may be considered mineral reactions; the sublimate of a constituent, and color given to H^{P} , &c., analytical reactions.

a system based on "metallic glance," "fusibility," &c., nearly identical with that published by the English AIKIN, "sixty years since," commencing with native Arsenic, and ending with Diamond, neither of which elements, by the way, can be strictly called a "mineral."

(204). Under such perplexities, I adopt for this work a classification more convenient for working with practically than scientific; if indeed there be any really scientific arrangement of minerals which is not purely crystallographical; for, as in organic nature, it surely ought to be the *form* itself we should attempt to classify, and not the chemical or electrical nature of the elements constituting the form; far less the manner in which that form bears heat, moisture, or the attack of acids, &c. With this view I have adapted the nomenclature of a system I found in the introduction to Des Cloizeaux's volume on the silicates, which, he tells us, is derived from the 'Traité de Minéralogie' of BEUDANT. In this arrangement, contrary to accepted terminology, the termination "ide" is used to denote the basic or radical element as well as the electro-negative one, which indeed, in Beudant's classification, is made to assume the terminal characteristic of a radical, as, e. g. "sulphurides."

(205). The favourite, and apparently the most scientific chemical mode of classifying minerals, is that arrangement under the banner, so to speak, of one of the mineralizing or petralizing agents above referred to, of all the metallic radicals or bases affected by that agency: thus "copper pyrites," which is a sulphide of both copper and iron, would be marshalled along with *Pyrite*, *Red-ruthite*, and *Argentite*; or with sulphides of iron, copper, and silver. *Cobaltite*, *Mispickel*, and *Proustite* would be thus found together, although radically consisting of such different metals as cobalt, iron, and silver. *Rhodocrosite*, *Siderite*, and *Marble* would be placed under one head, because carbonates; though composed of the widely differing metals, manganese, iron, and calcium, while some idea of the vast crowds of heterogeneous radicals which must flock together under this arrangement, to the rallying call of "oxygen compounds," may be derived from the fact that they occupy 588 pages of the large octavo volume of Dana above referred to. We find also that these oxides, sulphides, arsenides, &c., are seldom to be found in solitary possession of one or more radicals, but, on the contrary, are generally detected struggling with one another for that honour.

(206). If, on the other hand, the classist adopts the electro-positive radicals as the distinctive points of a mineralogical arrangement, he is often embarrassed by the necessity of selection between two or more of such radicals, and these in some cases, as, e.g. *Tetrahedite*, *Tourmaline*, *Labradorite*, &c., are so numerous and equally important, as to make any purely scientific selection a matter of simple

impossibility. For analytical purposes, however, there is generally some one of these radicals more *interesting* than the others, and this fact seems to be recognized in the very beautiful cabinets of minerals sold at the Freiberg University, in which, for instance, the last of the three above-mentioned minerals represents the sodium radical alone; and the second last, one of its smallest constituents—boric acid.

(207). Following then this practice—which is stated in the list of minerals given with the Freiberg cabinets to be sanctioned by Professor Richter—and adopting the curious but very suggestive *Beudant* terminology, I offer to the student the following *working* arrangement of minerals for pyrognostic analysis, which he will find, if less scientific, far more convenient than any other. The termination “*ide*” is not merely reserved in modern chemistry for designating the combinations of only four or five non-metallic elements, but is used *in addition* to the termination “*et*,” formerly and still possessed by the names of those combinations. This is a superfluity which our meagre chemical terminology can but ill afford, and in designating radical combinations by the termination “*ide*,” I have therefore fallen back on the old termination “*et*” to distinguish the combinations of non-metallic elements.

(208). HYDROGEN, Hydrates.

In this arrangement the hypothesis is adopted of the late Master of the Mint, that the *element* hydrogen, or hydrogenium, if not proved to be a metal, is not the gas, in which state only we have hitherto succeeded in obtaining it. The name is therefore placed at the head of this list of elements, as hypothetically occupying the first place on the left of the rectangular solar spectrum; or as an hypothetical line in the *pure* red at A (not the potassium (A) line, K α), the hydrogen gas spectrum “in the red” (H α) being here supposed to be due to a slight inseparable mixture of oxygen with hydrogen. It can be *proved* that most of the metals contain hydrogen.*

(a) Among other reasons for this departure from recognized chemical and spectroscopical classification, is the following one; but it must be here and elsewhere remembered by the reader, that, while not the slightest pretence is made to the assertion of new formulæ or “laws,” whatever deviation is made in this work from recognized principles has been made in consequence of a conscientious acknowledgment of the force of *stated* facts, which deviation, therefore, is more convenient, and indeed almost indispensable to the practical worker following the principles here followed. If we heat a fragment of pure lime in the strongest and hottest O.P., we get at first a slight but distinct orange-red coloration, to which the spectroscopists, increasing the reaction by means of hydrochloric acid, have given the position (Ca α) just to the right of C,

* Paragraph (29).

CARBON.

Copper

Cobalt.

Iron.

Nickel.

Uranium.

Gold.

Platinum, &c.

} Magnetic. }



on the solar spectrum. Without the acid, the "red flame" soon disappears; the fragment glows intensely, being perfectly incombustible, and then, of course, affords only a continuous spectrum. It was therefore naturally supposed that the HCl decomposed the lime, which latter was then burned, affording the (Ca α) line. But I found that by holding the fragment in H.P. (a comparatively cool position), the red tinge was increased; and following up this indication, I *first* made a very pure blue pyrocone from a pyrological candle, and *then* introduced the calcined fragment of lime, touching with it the wick of the candle. The effect was instantaneous, and almost magical. The blue pyrocone was completely tinged, indeed one may say dyed, with a magnificent orange-red* at the moment of contact of the lime fragment with the wick. When the former became saturated with oil the phenomenon ceased, but was easily renewed by heating the fragment slightly in O.P. and again touching the wick with it. Even a fragment of *Wollastonite* gave in this way a pyrochrome, which an observer not in the secret would have at once stated to be due to Strontia. Now, lime, being infusible in the hottest O.P., and yet affording this beautiful orange-red pyrochrome in the comparatively cold part of the flame, led me to suppose that the coloration must be due to a decomposition of the hydrocarbonous part of the latter; due, in fact, to the burning of hydrogen with a small mixture of oxygen. To prove the probability of this surmise, I weighed the fragment of *Wollastonite*, produced in this way the red light *for half an hour*, and, weighing it again, found it to be the same weight.

(b) The *gas* is but little evolved in pyrognostic experiments. It forms, however, one of the best tests for combined sulphuric acid, because it can be applied in the ordinary course of analysis,† without interfering with the immediate further examination. The sulphate, as, e. g. *Gypsum* or *Alunite*, is held in a pasty mass on a platinum ring, in a pure H.P., as that formed from a pyrological candle with a (β) or flat jet pyrogene. The sulphate is thus reduced to sulphide (without the necessity of heating it on charcoal, as usually recommended), through the mutual decomposition of the pyrocone and the sulphate held in it, the oxygen of the latter combining with the carbon of the former; and if a drop of distilled water be then added to the hot residue, the steam carries with it the rotten-egg smell of H_2S . Cobalt or manganese solution, or any of the regular tests, can then be added to the essay to detect the base.

(c) Hydrogen combined with oxygen as constitutional water, may be detected in almost every natural and artificial inorganic substance by means of $H\ddot{B}$,‡ and, *en revanche*, in that reagent itself by magnesia.§ This water is communicated in excess to boric acid by simply fusing it on a *large surface* of clean

* B, Plate II.

† *Vide* Paragraph (155, 4, d).

‡ *Vide* Paragraph (134, d).

§ *Vide* Paragraph (141, 3, a).

platinum,* when the glass formed is found to be dim or opaque on cooling, in proportion to the extent of surface contact between the flux and the metal. A *small* surface, as that of a wire, does not effect this, and the glass remains clear.

(d) A curious coincidence may be observed between this fact and the phenomenon that a platinum wire gives in O.P. the orange pyrochrome attributed to sodium only for a short time, while a larger surface, as of foil, affords it permanently.

(209). SULPHUR, Sulphurets, Sulphates, and Sulphites.

Sulphur, the very keystone of the noble structure called Modern Chemistry, without the analytical aid of which, that would pass away like

"The baseless fabric of a vision,
And leave not a wrack behind,"

is one of the most easily-detected constituents of minerals, furnace products, slags, &c. In a sulphuret containing a large quantity of sulphur, the latter *burns* on the application of H.P.; a considerable quantity evolves the *smell* of SO_2 , especially when heated *through* platinum†; and a proportion too small to do that, when powdered and ignited in a tube, will yet *red*den moistened *blue litmus paper*, which reaction, however, might in that case be due to SO_3 , or CO_2 . A very small proportion of sulphur is detected by treating a fragment of the sulphuret carefully at the bottom of a glass of $\ddot{\text{H}}\ddot{\text{P}}$ with a weak H.P. for a second only, when, at the commencement of its decomposition, the pungent smell of burning sulphur, or in case very little is present, a smell of H_2S is perceived, and at the same time a yellow streak is given off in the glass, like that of phosphate of silver, but proved to be not due to that, by its non-reappearance in H.P. after O.P.‡

(a) *Sulphates* are most rapidly detected by the dark stain they leave on polished aluminum plate, when heated with water on that, and by the rotten-egg smell of H_2S they evolve, when treated as in (208, b). Some sulphates, as, e. g. *Gypsum* and *Epsomite* (but I do not know of any other), afford this (H_2S) reaction so feebly, that it is necessary to take up a little soda on the platinum ring before moistening the hot mass with water, when a doubly-rotten-egg smell is evolved. The best of the first-mentioned reaction is, that *it is obtained in the ordinary course of analysis*, which should never be omitted, the drop of water being placed on a clean polished aluminum plate, and the hot steaming mass held under the nose.

(b) The difficulty the analyst experiences is not, as one would suppose from reading the tests in works on the blowpipe, to *prove the existence* of sulphur in a

* Vide Introduction, Paragraph (15).

† Vide Fig. 55.

‡ Vide Argentides.

sulphate, by converting that to a sulphide of sodium, or of silver, with those tests, but to know that in the earthy, or transparent, or chalk-like mineral before him, the *necessity for applying such tests exists*. For instance, Von Kobell says, in his 'Bestimmung der Mineralien:':* "*Example*.—One has to determine *Aluminite*. . . . We find in the table that both the minerals *Alunite* and *Aluminite* give a hepar with soda. Our mineral affords this reaction," &c.; but the writer does not give us the least indication of the feeling or suspicion which led him to fuse these minerals with soda in the first place.

(c) Some sulphates, as *Barite* and *Celestine*, when treated on an aluminum spoon in a candle H.P., after being moistened with water, have the curious property of yielding sulphur as a yellow incrustation, instead of, as one would have supposed, being converted into sulphides of their bases. It seems that a fresh economic value would be given to *Heavy spar* by the knowledge of this reaction.

(d) The exact color of a sulphisodic hepar—as may be seen by fusing on aluminum plate a fragment of pure soda, with one about equal in bulk of pure sulphur, in H.P.—is a very pure and delicate salmon color. In minute proportion, as derived from an H.P. of coal gas, the soda bead becomes pale pink on cooling. When iron oxide is present, a salmon-colored stain (apparently consisting of sodiferic sulphide) will generally be found at the bottom of the bead, where it has been resting on the aluminum; the rest of the bead is yellowish-green, becoming blackish by keeping. The above is the best way of testing for sulphur in gases.

Sulphur is easily detected in a single hair of the beard, by rolling it up between the fingers to a ball, placing over it on aluminum plate a bead of pure soda (which has been previously found by the H.P. of a pyrological candle, for gas must on no account be used, to cool to a perfectly white bead), and treating both with a pure candle H.P. On cooling, the bead will now become a pale salmon color; if there be also magnesia present, bluish; if lime, purplish at the bottom. It seems that this would form an excellent, rapid, and cheap method of purifying coal gas from its sulphur compounds, which, as stated lately by Mr. Vernon Harcourt, there are at present no means of doing; for if house-coal gas be passed over pure soda moistened with distilled water, and that be tested in the manner above described, a pink bead will be produced.

(e) The *confirmation* of the existence of S, SO₂, or SO₃, is made by (VII. a, b, or c), according to their proportion in the mineral; also by (VIII. 5), Paragraph (140). The existence of the *acid* is proved by (XI. j), Paragraph (155).

(210). SELENIUM, Selenets, Selenates, and Selenites, are detected by the

* Page viii., Introduction. Tenth edit. 1873.

same tests as sulphur and its corresponding acids. The former are easily distinguished, by the *smell* of horse-radish, from the latter, when heated in H.P.

The only substance for which Selenium in combination could be mistaken is Tellurium, which also emits a peculiar smell in burning, though not exactly that of horse-radish; they are, however, easily distinguished in any combination by the peculiar selenic sublimate on aluminum plate.

The following is an essay of Tilkerode *Clausthalite*: (1) On aluminum plate in O.P. (a) A brownish-black velvety halo, with white over that, turning black instantaneously in O.P. (b) Above the white, a broadly-spread, thin, semi-metallic looking, copper-colored sublimate, turning bronze in O.P. (Se). (c) Bright blue pyrochrome. (d) Smell of rotten horse-radish. (2) On wiping (a) away with a silk cloth, a bright brick-red stain was found under the essay, which turned bronze in O.P., with blue pyrochrome. (3) The essay only partly fused (differing from Tellurium). (4) No sublimate on steel forceps (distinct from Bismuth).

(211). NITROGEN, Nitrogenets, Nitrates, and Nitrites.

Far within the Himalaya Mountains, in exposed places, but miles from any human dwelling, the rocks, especially those of limestone, may be observed perfectly black on the surface. This is what the geologists call "weathered;" but to what cause is this blackness to be ascribed? In the neighbourhood of a town, one might easily imagine it due to fine particles of soot deposited; but where there had been no smoke since these mountains were upheaved, there could be no soot. A little of this black part of the rock, scraped off and heated in a tube, closed with the finger, gives off a smell like that of burning fat. Some minerals, as, e.g. *Stinkstone*, crushed, and thus heated, afford the same reaction, and these are generally black. Either of these powders dissolved in an $\ddot{H}\ddot{P}$ glass in O.P. affords no color for some time, but eventually, with further additions of the substance, the glass being colorless hot, becomes yellowish and jelly-like on cooling. The same effect is produced by dipping the red-hot glass in concentrated nitric acid, or in the strongest solution of ammonia, holding it for some time in the H.P. of a pyrological candle, and then treating it with P.P. The discoloration of the surface of these rocks, therefore, I suppose to be due to nitrogen; not a very surprising circumstance, when we consider that they had been for so many centuries exposed to a mechanical mixture like air, consisting of four-fifths nitrogen gas.

(a) The substance suspected to contain nitrogen, either in this form, or as nitrate, or nitrite, should be manipulated as in Paragraph (136, V. 3, j).

(b) The black flakes which nitrogen affords when heated in O.P. on an

$\text{H}\ddot{\text{B}}$ glass, are far more infusible than carbon is, from which, therefore, this element may be thus distinguished in organic essays, grains of wheat, &c.*

(c) Nitrogenous phosphates, as, e.g. those derived from the calcination of a grain of wheat or barley, &c., or of urinary or other calculi, are, if not previously very strongly ignited in O.P. as a paste on aluminum plate, utterly indecomposable in $\text{H}\ddot{\text{B}}$, the phosphate, whether of calcium, magnesium, or other base, being mechanically dissolved to a clear glass by the addition of sulphuric acid and potash, without the liberation of any phosphoric acid.† An approximate estimation, therefore, of the amount of nitrogen may be made by the proportionate difficulty of decomposing the phosphate in $\text{H}\ddot{\text{B}}$.

(212). CHLORINE, Chlorinets, Chlorates, and Chlorites.

When chlorine is combined with any white infusible substance, as the earths, for even Baryta is not fused in a weak H.P., the treatment as in Paragraph (134, III. g) will at once detect it, after the observer has had some practice. If the substance is extremely fusible, as, e.g. sodic or calcic chlorinet, it should be enveloped in the H.P. from a pyrological candle, weaker even than that represented from a lamp, by Fig. 15. The side next the pyrocone or front of the essay will then be found to rapidly assume a black oily appearance like coal tar (carbonic chloride?), while the back, as in O.P., is clear hot, opaque white cold. If the earth is dark or colored so that this reaction would be disguised, it can be mixed to a paste with a little lime, when the black spot in front will appear on a white ground. When there is a large quantity of chlorine present, as in common salt, the bead (for it rapidly fuses) in H.P. will boil strongly, and when removed under the nose, gives a suffocating smell of chlorine, which a drop of water stops at once. After some treatment with H.P., free chlorine is not given off, but the black patch in front is formed as before.

(a) A very delicate test for chlorine is that given in Paragraph (140, VIII. 4, b). I thus detected a small quantity in lithographic limestone, the presence of which as "a trace" was confirmed by a chemical analysis.

(b) Chlorine is also rapidly detected as in Paragraph (140, VIII. 6, a), for the idea of which I was indebted to Normandy's 'Chemical Atlas.' It is the best, because most simple and rapid adaptation of the discovery of Bergman, that cupric chloride gives a *blue* pyrochrome. The curious fact that if the essay be held at all *inside* the flame, the blue pyrochrome at once ceases, while, in the case of NaCl, the orange pyrochrome of Na is copiously afforded in that situation, seems to show that what burns is either a chlorite or chlorate.‡

(c) The chloride of a fusible metal, as, e.g. of silver, should be made into

* Paragraph (268, c).

† Paragraph (212, g).

‡ Vide Paragraph (208, d).

a paste with lime and a drop of copper solution, and treated as in (134, III. *w*).
(Type: common salt.)

(213). FLUORINE; Fluorinets.

Fluorine is tested for, as in (212), only the spot or patch formed in front by H.P. is green instead of black. When a large proportion of fluorine is present, as in fluor spar, the mass also glows with a phosphorescent light in cooling.

(a) The test (140, VIII. 5, *b*) is a delicate one for small quantities of chlorine, for the resultant beautiful pure blue color cannot well be confounded with the green-blue produced by addition of sulphuric acid; the difference may be easily seen by looking at the two beads together by reflected light, in one of the German penny bottles. Still less can it be mistaken for the blue-green of cupric oxide in $\ddot{H}P$, or P. salt; which, however, writers on the blowpipe seem to call "blue."* The best way to prove this assertion is to look at the three beads together.

(b) "When fluorine occurs in trifling quantity with weak bases and a little water in minerals, it is only necessary to heat a small quantity of the substance in the closed glass tube, in which a strip of moistened Brazil wood paper is inserted. The gaseous fluoride of silicon expelled by the heat is decomposed by the vapour of water, and a ring of SiO_2 is deposited near the assay, while the escaping HF colors the paper straw yellow. This reaction is produced when only $\frac{1}{2}$ per cent. of fluorine is present, as in Mica."†

(c) Fluorine may be detected by reversing Dr. Turner's experiment for the detection of boric acid in Tourmaline, i. e. by mixing the latter, powdered, into a paste with $KHSO_4$ ("bisulphate of potash"), and with the essay; treating it with O.P., when, without fluorine, the green pyrochrome cannot be produced.

(d) I got a transient, but very distinct blue pyrochrome of chlorine, by grinding fluor spar into a paste, with a drop of sulphate of copper solution, and heating in H.P.‡ A very slight proportion of fluorine, as, e. g. in *Apophyllite*, may be detected by heating the mineral with a little potassic carbonate on burnished aluminum plate, when, if in small quantity, an iridescent halo, and if in large, a white sublimate (apparently consisting of fluoride of potassium) is produced. Either of these is at once distinguished from faint arsenical sublimates, which resemble them, by the addition of a drop of water; when the former are instantaneously dissolved, and disappear.

(214). BROMINE, Brominets, Bromates.

To distinguish brominets from chlorinets with certainty, they should be

* "Nach dem Erkalten, blau, bis, grünlich blau." Plattner, p. 129.

† Plattner, p. 487, American translation. 1872.

‡ *Vide* Paragraph (130, III. *w*).

fused in a test tube, closed by the finger, with (KHSO_4) , when bromine and SO_2 are liberated, and the tube is filled with reddish-yellow vapours of bromine, which can be recognized by the similarity of their odor to that of chlorine, notwithstanding the SO_2 ; but bromide of silver forms an exception, and may be distinguished from AgCl by the asparagus green color which it assumes in sunlight after fusion with (KHSO_4) .^{*} This element, and the one next named, are so little met with in the analysis of natural inorganic substances, that a detailed notice of either is not necessary. (Type: *Bromyrite*.)

(215). IODINE, Iodine, Iodates.

Iodine in very small quantity may be recognized by the well-known violet vapour which fills a closed test tube when any substance containing it is heated in that. This vapour, or any iodate, also gives an intense blue color to a solution of starch—a still more delicate test, but not “within the province” of this work. (Type: *Iodyrite*.)

(216). PHOSPHORUS, Phosphorets, Phosphates.

The last are indicated by heating the phosphates on burnished aluminum plate strongly in O.P., and quenching the hot mass with a drop of water, by which those of the alkaline earths, as, e. g. *Apatite*, are partly decomposed; and when this is repeated once or twice, leave an iridescent dark metallic stain on the plate. The stain left by sulphates thus treated is more black and less iridescent than that of the former; and if a sulphate be added to that, and heated, the stain left is, after a short time, white and metallic, like tin plating, and is then not easily removed, even by moistened emery cloth. This indication is especially valuable, because it occurs in the ordinary course of analysis. It is confirmed by procedure as follows:

Few substances are more rapidly detected pyrologically than free phosphoric acid, although, on the other hand, it is in many cases only with difficulty freed from its combinations. Even .2 per cent. of it, though in conjunction with ten bases, silica, and fluorine, as, e. g. in *Tourmaline*, is at once betrayed by the simple application of the finely-powdered mineral to $\text{H}\ddot{\text{B}}$ under O.P., when a trace or streak of the peculiar blue opaline matter due to $\text{H}\ddot{\text{P}}$ is *first* perceived, if the bead be not held long enough in O.P. to decompose any of the various bases. A trace, i. e. a fragment the size of a small pin's head, of the “glacial” phosphoric acid, applied to a 50 mgrs. bead of $\text{H}\ddot{\text{B}}$, in which it dissolves under O.P., causes the latter to assume the appearance, on cooling, of the “noble opal,” but this beautiful imitation does not last, as the bead becomes opaque and white by attracting atmospheric moisture. If, however, a silicious jelly be made, by boiling silica in fluid phosphoric acid, and $\text{H}\ddot{\text{B}}$ cautiously added,

^{*} Berzelius, as quoted by Plattner, American translation, p. 482.

an imitative opal can be made, which seems to retain its color and lustre unimpaired.

(a) One of the most important applications of this pyrological detection of phosphorus is in the case of "pig" or cast iron, which, the ironmasters say, must not contain even .5 per cent. of the element, or it will be so brittle and crystalline as to be what is technically termed "cold short," that is, pieces of it break short off even when cold. Pure, or nearly pure, iron, as, e. g. piano wire, is utterly unchanged in $\ddot{H}\ddot{B}$ under O.P., but, if it contain the slightest trace of ferric phosphide, that turns black, especially when the fragment touches the platinum wire of the bead, which it should be made to do; at the same moment streaks of grey opaline matter are given off from the fragment, which become opal blue by addition of a minute speck of potassic carbonate; if too much of this be added, the glass will become clear and the reaction lost, but can be regained by the re-addition of $\ddot{H}\ddot{B}$. Grey opaline matter is also produced by chemical hydrates,* but the addition of any potash, however minute, clears it, without first rendering it blue, and the opalidity is not revived by the addition of fresh boric acid. Sodid carbonate has the same capabilities, but potassic is preferred, because the former orangizes the green pyrochrome, and thus prevents the operator from detecting soda, should there be any in the essay.

(b) Some of the phosphates of alkaline earthy bases form opaque balls in $\ddot{H}\ddot{B}$, as does what is called "bone-earth calcic phosphate." *Apatite*, *Sombrerite*, and urinary calculi, on the other hand, are utterly unchanged from the fragments in which they were applied, no matter in how fine a powder, or under any O.P. however strong,† and that combination might therefore be called, in contradistinction to "bone phosphate," "stone phosphate" (of calcium). Hydric sulphate seems far the best reagent for decomposing all obstinate phosphates; but as this system does not admit the use of the acid *pur et simple*, which belongs to "the wet way," it must be applied in combination. Sulphates of the alkaline metals will not do, as their bases, combining with $\ddot{H}\ddot{B}$ under O.P., constitute a flux which dissolves phosphoric acid, and almost everything else, to a clear glass; thus spoiling, of course, the detective properties of $\ddot{H}\ddot{B}$; and as magnesian sulphate is one of the best detectives of phosphoric acid in the wet way, I tried that salt as follows:

(c) To detect $\ddot{H}\ddot{P}$ in *Wavellite*, for instance. About one-tenth (a pin's-head crystal) in volume of magnesian sulphate is added to an $\ddot{H}\ddot{B}$ bead, and the resulting ball dissipated by the cautious addition of specks of crystallized K_2CO_3 ; for

* Paragraph (208, c).

† I succeeded, however, in fusing a small pin's-head fragment of *Apatite* to a ball in the $\ddot{H}\ddot{B}$, by means of a high-angle O.P. on a "ringed bead"—Paragraph (140, B).

if too much be added, a flux is formed which dissolves the \ddot{H} .^{*} The slightest speck of *Wavellite* now added to this bead is decomposed; the Al_2O_3 slowly dissolving, and the \ddot{H} affording the usual blue opaline matter, rendered still more apparent by the further addition of \ddot{H} , which, if a considerable quantity of \ddot{H} has been liberated, renders the whole bead opaque white. If one-third in volume of magnesian sulphate be added, with proportionate potassic carbonate, to the \ddot{H} bead in the first place, the slightest addition of *Wavellite* causes, as by magic, beautiful filamentary crystals to spring through the glass, which the further addition of calcic phosphate destroys; nor can they again be produced in the same glass. As apparently similar crystals can be produced in an \ddot{H} glass by saturation with magnesian sulphate, and the solution of that to a clear glass by potassic carbonate alone, under O.P., without the addition of any phosphate, the glasses containing both kinds of crystals should be placed side by side in the focus of the microscope,† when the difference will be easily perceived: the sulpho-magneboric crystals are so fine as to resemble those of *satin spar*, and generally radiate from a solid nucleus of undissolved essay; the phospho-magneboric crystals are much coarser, and scattered over the glass. The addition of potash to this glass acts like that of water to a crystallizing liquid, obliterating the crystals: that of \ddot{H} increases the tendency to crystallize: that of either essay has a tendency to collect the crystals into solid amorphous masses again. If free phosphoric acid be produced in the \ddot{H} glass by the solution in it of fragments of the essay by the addition of a speck or two of potassic carbonate, and a pin's-head crystal of *Epsomite* be then added, beautiful opaline balls of magnesian phosphate are produced, some of which under the microscope are yellow, showing the presence of ferric oxide.

(d) Phosphoric acid combined with lime has, apparently, the curious property of concreting (that is, a molecule draws all round itself) the earths and alkaline earths, forming eventually nodules, more or less hard according to the nature of those. Even the purest limestone, as that described below,‡ contains a trifling proportion of hydric phosphate, while some, as the oolitic limestone I tried, must have at least 2 per cent., and *Kunkur* a very considerable amount indeed. Among some thousands of experiments I have made, I never yet found a natural limestone absolutely free from phosphoric acid; and if, as would appear to be the case, that is an essential constituent of the former, some clue would be afforded to the unexplained phenomenon of "setting," both hydraulically and pneumatically, which belongs especially to lime compounds. On this hypothesis, in lime with a very small proportion of calcic phosphate, distributed equally through the whole volume, the concretionary tendency of one molecule of calcic

* *Vide* (a).

† Paragraph (100).

‡ Paragraph (226, d).

phosphate would be balanced by that of the neighbouring molecules; so that, instead of a lump or nodule round the former, a hard mass *over all* would be formed. With the exception of sulphur, which, combining with iron, forms analogous nodules in *Pyrite*, no other substance seems to possess this concreting power; and there is, I believe, no instance of a concretionary stone, from those found in the bladders and joints of some animals up to the coral reef of the Pacific (attributed, but not exclusively, to lime-secreting *Zoophytes*), which has not its nucleus of calcic phosphate. Even glue owes, according to Liebig,* its binding property, in a considerable measure, to the calcic phosphate it contains, and loses its property of gelatinizing when that is separated.

(e) When a calcic silicate, as *Wollastonite*, is crushed and boiled with about one-third of fluid phosphoric acid to two-thirds water, the silica separates, being dissolved, and on cooling forms a jelly (*a*). The residue (*β*) consists of "stone" phosphate of calcium, unaltered in $\text{H}\beta$ like *Apatite*, while there are no indications of lime in (*a*), or of silica in (*β*). The curious similarity in shape (like the kernel of a walnut) between the concretionary flints found so abundantly in the English chalk formation, and the generality of kunkur nodules, has not been remarked. In the former case the nucleus is generally a fossilized sponge, shell, or coral, consisting chiefly of calcic phosphate; the latter usually consist of the aggregation of an immense number of small nodules, each probably containing a nucleus of calcic phosphate; but I have a curious specimen of kunkur, from the "*Kari Nuddes*" Agra district, having a ludicrous resemblance to the fossilized socket of a human bone. Further reference will be made to phosphoric acid under the head of "Agricultural Analysis."

(f) Metallic phosphates, such as *Pyromorphite*, betray their phosphoric acid on aluminum plate in a very characteristic manner. Treated with O.P. on the charcoal mortar, a curious bluish-grey, semimetallic, leaf-like stain spreads over the white, yellow, or brown sublimes formed, which is proved to be crystalline by the operator leaving the plate untouched for several hours, when the stained part is found covered with semitransparent polyhedral crystals of some pyrophosphate, which become opaque white, but are otherwise unattacked in $\text{H}\beta$ under O.P., remaining as amorphous fragments like alumina. But the very peculiar and interesting fact is observable that, wherever the pink or silver sublimate occurs,† none of these crystals are superposed; but the sublimate, instead, seems to swell out in carmine balls, some of which have as fine a color as the cochineal *Coccus*. This reaction, however, should not be allowed to take place, as the aluminum is gradually corroded; from which fact it is concluded that the crystals described are aluminic phosphate, as above surmised.

* 'Letters on Chemistry,' p. 409, note. † All lead ores contain a trace of silver—Paragraph (241, d).

(g) Organic mineral phosphates, as, e. g. calculi urinary, biliary, or gouty, require, either on account of the presence of uric acid, or of some other organic or nitrogenous matter, which interferes with the usual reactions in $\ddot{H}\ddot{B}$, a method of analysis particular to themselves; as follows:

(1) A fragment is heated to redness only* on aluminum plate, and quenched with water two or three times, when a black stain, not iridescent, shows the presence of sulphur. If this water is feebly acid, it is tested for uric acid by adding a crystal of nitre, which immediately becomes brick red.

(2) The fragment is now crushed to a paste between agates, and very strongly ignited in O.P. on aluminum plate, for the purpose of burning the nitrogen, which is very difficult of combustion and interferes with the $\ddot{H}\ddot{B}$ test for phosphoric acid, † fragments of calcic phosphate not even congesting into balls.

(3) A glass is prepared by fusing two pin's-head fragments of pure *Gypsum* and boric acid together on a platinum ring to a white opaque mass. This is clarified by the cautious addition of potassic carbonate in specks, when the *Gypsum* is mechanically dissolved (with the exception of a white semiopaque ball, which generally forms on the glass cooling) in the potassic borate.

(4) The nitrogenous phosphate is now added to this glass, in which it rapidly dissolves mechanically, with evolution of much gas, to a clear glass; unless much magnesia is present, when magnesian phosphate crystallizes out in beautiful needles.

(5) This glass is unrolled off the wire, crushed, and one of its fragments added to a fresh $\ddot{H}\ddot{B}$ glass under O.P., when the opalescence of $\ddot{H}\ddot{P}$ spreads, on cooling, over the glass. *Gypsum* alone, similarly treated, forms opaque white fragments in fresh $\ddot{H}\ddot{B}$, without opalescence.

The *rationale* of the process seems that sulphuric and phosphoric acid mutually dislodge each other, in $\ddot{H}\ddot{B}$ under O.P., from combinations. The former is chiefly volatilized as SO_2 , the latter, being fixed, shows itself in $\ddot{H}\ddot{B}$ not combined with too much potash; while the bases are dissolved, or partly so, in the potassic borate.

(h) One of the most rapid, effective, and striking tests for phosphoric acid in substances where there is no chromatic metallic oxide to interfere, that is, in substances where it is generally to be looked for, and its detection is of most importance, as in the earths and alkaline earths, is supplied by the following procedure. Plattner, and other subsequent compilers of the ordinary 'Blowpipe

* In examining some human urinary calculi, kindly given me for the purpose by Dr. Wadham, of St. George's Hospital, London, I detected in one sort, by heating the fragments alone on aluminum plate, both antimony and arsenic in extremely minute quantity; the latter as an iridescent tarnish, the former as a faint white sublimate, which blackened in O.P.—Paragraph (129, g).

† Paragraph (209, c).

Tables,' do not seem to have paid any attention to the very remarkable fact there detailed by them, that Tungstic acid, or "Wolframsäure," as the Germans call it, yields in the "reducing flame" a yellowish-brown ("unter der Abkühlung gelblich braun") color to a bead of sodic borate (borax); but a blue color to a bead of sodic phosphate (microcosmic salt). The soda being common to both fluxes, it is evidently phosphoric acid which causes the blue appearance of tungstic acid in the latter, and that may, or may not (the fact, here, is quite immaterial) be due, as the chemists assert, to "Tungstous Tungstate" (WO_2WO_3). Whatever it is, *phosphoric acid causes it here to appear*. Moreover, I found* that iron and manganese oxides do not destroy the blue in $\ddot{\text{H}}\text{B}$, as they do in microcosmic salt, but heighten its tone. The operator, therefore, constructs a test glass for phosphoric acid, as follows: A clear, pure glass of $\ddot{\text{H}}\text{B}$ is first fused on a platinum ring; on both sides of this, while hot, is taken up as much pure, powdered tungstic acid, as each will carry. The mass is digested with potassic carbonate in O.P. until clear, but of a yellowish-grey color; the application of P.P. will then make it clear and colorless. To this potassic tungstiborate glass, a few powdered specks of the phosphate are added in O.P. *Wavellite* rapidly dissolves; *Apatite* is more obstinate, and requires a speck or two more potash, until the glass is evidently alkaline.† In either case, a short H.P. produces, just as the glass becomes cold, a beautiful purple‡ tint.§ Sulphates emit perpetual bubbles (of SO_2) in this glass until the essay is dissolved, bestowing on it no color; but the addition of any substance containing phosphoric acid at once produces the purple color. I discovered this test in June, 1874.

(i) In conducting the above operation, if the phosphatical essay be *first* added to the $\ddot{\text{H}}\text{B}$ glass, and then dissolved in that, by means of the further addition of potassic carbonate under O.P., a mechanical solution, not a chemical decomposition of the first, seems to ensue; for, if we *now* add the tungstic acid, and also dissolve it, not a blue, but brownish-yellow glass—a potassic tungstiborate—is obtained, while crystals, apparently of tungstic phosphate, appear; while the same phenomenon seems to ensue if too little tungstic acid (in testing for a *small* proportion of phosphoric acid) has been dissolved in the glass in the first instance, which may easily happen if the former (reagent) be as impure as it is sometimes procured in London. It is, therefore, absolutely necessary to proceed as directed in (h). The *rationale* of the process seems contained in the fact of the attraction possessed by some oxide of tungsten for phosphoric acid, and (according to the present chemical theory, which is by no means clear) the liability of the latter to reduce tungstic acid to an apparently lower oxide. The same fact surely

* Paragraph (248). † *I. e.* when the green pyrochrome is changed to violet—Paragraph (108).

‡ Due to the combination of the colors yellowish-brown and blue.

§ 2·9 Pl. III.

shows that it is not so immaterial as writers on the blowpipe have assumed, *which* constituent, in the concoction of a flux, we *add first*?

(*j*) The lurid green pyrochrome afforded by free phosphoric acid in H.P. is not to be depended on as a test for that in combinations, (*a*) because in O.P. its pyrochrome has a red-orange color; and (*β*) because the orange pyrochrome given by almost all substances containing water disguises it completely. Still less can the operator depend on the iron-wire method devised by Berzelius. Some idea of the complexity of the other plan (still adopted) suggested by the same celebrated chemist, of fusing the phosphate with four parts of soda to one of silica, boiling the mass in water, adding plumbic acetate, &c., may be formed from the fact that a description of it occupies *three closely printed octavo pages* of Plattner's 'Probirkunst,' &c.!

(*k*) The success of the process here given, chiefly depends, like the one above described,* on the *fixity* of phosphoric acid, and the *volatility* of sulphuric and arsenic acids, in $\text{H}\beta$, under O.P. (Types: for (216), case-hardened steel filings; and secondly, iron phosphide; for (216) (*a*), *Tourmaline*; for (216) (*b*), *Apatite*; for (216) (*c*), *Wavellite*.)

(217). BORON, Borates.

Boric acid, although by far the most important pyrological reagent, is not apparently considered of much value in natural products, except when combined with soda, as in borax, the estimation of which can be best made alkalimetrically. It is, however, especially interesting to the analyst, from the very difficulty there is in detecting it in such minerals as *Tourmaline*; that is, without a supply of KHSO_4 and fluor spar, the former of which is troublesome to keep, and not procurable in "the Jungle." The following method is not so pretty or effective as that invented by the late Dr. Turner (who, by the way, does not seem to mention his method in his 'Chemistry'); but after a little practice, the reaction this gives is so easily observed as to be equally certain in the object required, while the reagent (sulphate of copper) is useful for other detections, as for chlorine, and may be procured pure enough for the purpose in most Indian bazaars. It will be observed that metallic copper does not afford the green Cu. pyrochrome in O.P. until a coating of the suboxide has been formed on the metal, and it is *that* which colors the O.P. green; for the natural suboxide (*Cuprite*) affords the color vividly and immediately. It must have been also observed that the yellowish- or pea-green pyrochrome of $\text{H}\beta$ becomes intensely vivid by the addition of a copper oxide, and then appears to have a bluish tint, almost like that of cupric chloride. By careful comparison of this $\text{H}\beta$ Cu. pyrochrome, however, with that of *Cuprite* (which has a bluish tint) held alongside,

* Paragraph (216, *g*).

it will be seen that the latter is quite the same as the former. We have, in fact, been deceived by our eyes into imagining that a brilliant bluish-green tint has been given to the yellowish-green one, whereas that has disappeared altogether, and has been replaced by the former.*

(a) Now it will be found, by grinding any earthy minerals not containing chlorine or boric acid into a paste, between agates, with a drop or two of copper sulphate solution, that, after the first few seconds, when the superficially reduced cupric suboxide affords during that time only its bluish-green pyrochrome, no distinct color of any kind is given to the flame, the pyrocone being merely tinged with the normal orange, produced by most substances, especially when moistened with water.

Very different is the behaviour of substances containing even a trifling proportion of $\ddot{H}\ddot{B}$, as, e.g. *Tourmaline* or *Axinite*. A fusible borate of suboxide of copper seems to be formed, which burns with a fine green pyrochrome, more distinct and durable in proportion with the strength and continuance of the O.P. applied, while the reaction afforded by $KHSO_4$ and fluor spar is only momentary.† *Example*.—Crush a fragment of *Zoisite* into a paste with a drop of Cu. solution, between agates. On a platinum ring, after the first few seconds, the mass affords only an orange pyrochrome. Crush the *same* mass into a paste again, with the addition of water and a fragment of black *Tourmaline*; in a strong O.P. after some time, it will afford a distinct and continuous green pyrochrome. (Types: *Tourmaline*; *Axinite*.)

(218). SILICON, Silicates.

Silica, as in hydracid analysis, can be operated on under two modifications, (a) soluble, and (β) insoluble (in $\ddot{H}\ddot{P}$). Hydric silicates, as *Tabasheer*, are most soluble; but most natural silica can be dissolved to a considerable extent (about 10 per cent.) by carefully keeping the $\ddot{H}\ddot{P}$ glass between it and O.P.

Silica fused with pure lead affords a substance which renders an $\ddot{H}\ddot{B}$ glass very opalescent, even with excess of $\ddot{H}\ddot{B}$ (distinct from tin and alumina), having insoluble fragments floating in it.

The element is never found in nature, and in common artificial products scarcely ever, except in cast iron.

* Paragraph (109).

† "The fine powder is mixed to a paste with a little water, and 1 part of a flux consisting of $4\frac{1}{2}$ parts of bisulphate of potash and 1 part of finely-powdered fluor spar, perfectly free from boric acid. It is then fused on platinum wire within the blue flame, and as soon as the water is expelled fluoboric acid is formed, which is volatilized, and imparts a yellowish-green tinge to the flame. This coloration is very transient, however, and must be looked for with great attention if little boric acid is present. According to Merlet, three to four parts of the flux are requisite to obtain a sure result." (Plattner, American translation, p. 468.)

(a) *Silica* is the cuckoo's egg of inorganic nature. It is found, in different states of combination, with almost every known "electro-positive" radical, and has a (comparatively) rare home of its own in quartz and opal. In the enormous range of its natural combinations, i.e. the vast "family" of silicates, it is itself unchanged; but the bases which combine with it are, according to the last generation of chemists, found in many states of oxidation, and the complication thus arising is further complicated by the extremely numerous instances in which *water* forms (apparently) an essential part of the silicate; so that a scientific arrangement of the silicates, that is, one in which the rules or "laws" by the authority of which the different species are placed, admit of few exceptions, is a matter of great difficulty. The simplest and best seems to be that proposed by Dana, who classifies the silicate according to the accepted proportion the silica bears to the quantity of *oxygen* in the base, thus:

1. Bisilicates, in which the oxygen of the base is to the silica as 1 : 2.
2. Unisilicates, " " " as 1 : 1.
3. Subsilicates, " " " as 1 : $\frac{2}{3}$, $\frac{1}{2}$, or $\frac{1}{3}$.
4. Hydrosilicates include the above.

(b) Berzelius, on the contrary, arranges the silicates according to the number and species of bases combined, thus: (1) Silicates with one base. (2) Silicates with several bases. These are subdivided into classes, according to the accepted proportion between the silica and the quantity of *base*, thus: Two-thirds silicate of lime CaSi_2 . Neutral silicate of lime CaSi . One-third silicate of lime and alumina $\text{Ca}_3\text{Si} + 2\text{Al}_2\text{O}_3\text{Si}$. This is obviously a less scientific arrangement than the oxygen ratios of Dana, because the bases are constantly subject to replacement, one by another, while the relative amount of oxygen in those bases is often identical; but at the same time, it is a far more convenient classification for the qualifying analyst, who does not want to find the relative amount of oxygen in the base, or of silica, but to detect the different bases themselves in combination; and Plattner also has recognized this fact, by placing the silicates under basic headings, in which method, however, there must be a deal of arbitrary selection.

(c) I have therefore, for the convenience of the analyst, compiled the following table of silicates, in which they are arranged, alphabetically, according to the relative *quantity* of the principal bases combined, which are indicated in that order, by a sufficient part of their common chemical names, to be at once recognized, without making the word too long, or, if the accents are attended to, at all difficult to pronounce, while the very act of pronunciation gives the reader, in each case, a fair idea of the chemical composition of the whole silicate, thus: *alu-magne-calci-férric silicate*, in which, of the bases, alumina is present in

largest quantity; then magnesia; then lime; and lastly or least, iron. *Clintonite* or *Seybertite* is the here-selected type of this class, which is found by the index under the letters A. m.; alumina being the largest base, and magnesia the next. Thus, again, under C. m., *calci-mágnálu-sódi-férri-mangánic* silicate, of which *Violane* is the quoted type. *Hýdroferrimágnemangánic* silicate (*Cronstedtite*). These three instances are among the longest words, and will not be found difficult to pronounce. Each accent not only shows the syllable on which emphasis is to be put, but generally covers a base.

SILICATES, ALPHAQUANTITATIVELY ARRANGED.

[The minerals marked (*) are sold in a cheap cabinet (I forget the name) at Freiberg. They are evidently carefully selected, but no localities are given.]

A.

- I. *Álumínic silicates*. (a) Andalusite; (b) Chiasolite; (c) Sillimanite; (d) Cyanite, Disthene.
- II. *Álúborisódic silicates*. (a) Oural Tourmalines.
- III. *Álúdcálcic silicates*. (a) Melonite; (b) Ekebergite; (c) Scapolite; (d) Couzernite; (e) Scolexcrose; (f) Atheriasite; (g) Zoisite; (h) Saussurite; (i) Anorthite.
- IV. *Álúdcálciferribóric silicates*. (a) Axinite.
- V. *Álúdcálcisódic silicates*. (a) Nepheline; (b) Elæolite; (c) Labradorite; (d) Le-manite; (e) Andesine.
- VI. *Álúferric silicates*. (a) Staurotide.
- VII. *Álúferrimagnésic silicates*. (a) Gigantolite; (b) Iberite; (c) Fahlunite; (d) Weissite.
- VIII. *Álúfluóric silicates*. (a) Topaz.
- IX. *Álúglúcnic silicates*. (a) Emerald; (b) Euclase.
- X. *Álúlitic silicates*. (a) Triphane; (b) Petalite.
- XI. *Álumagnésic silicates*. (a) Lindsayite; (b) Sapphirin.
- XII. *Álumágnébóric silicates*. (a) Carinthian Tourmalines.
- XIII. *Álumágnédcálciferric silicates*. (a) Clintonite.
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N.B.—The object of the above (very incomplete) arrangement is to afford types of the required base or acid, as much disguised by the chemical or mechanical combination of other bases or acids as possible, so that the student may here have the most difficult form of identification. The easiest form, i. e. blocks of *Malachite* or *Cuprite* in the case of copper, is the common fault of cabinets.

(d) Uncombined pure silica is at once detected by its ice-like appearance in $\ddot{H}B$, in which it floats, a nearly transparent mass, utterly insoluble; a fact I have proved by weighing a fragment, treating it in $\ddot{H}B$ under O.P. for half an hour, extracting it with boiling water, and reweighing, when the weight was the same. The test for silica usually adopted, of its supposed insolubility in P. salt, "the bases combining with the free PO_5 , leaving the silica undissolved,"* is far from being absolutely correct, as at least 6 per cent. of silica is dissolved by P. salt under O.P., but for any silicate containing more than that quantity this qualitative test answers tolerably well.

(e) As alumina powder gives white fat-like fragments in $\ddot{H}B$,† it is quite easily distinguished from silica when the two earths are mechanically combined; but when the essay is a silicate of aluminum (the combination generally found in nature), if there is an excess of silica (especially when, also, an alkali is present in small quantity, as in *Feldspar*, &c.), the icy mass is formed, although alumina is contained in it, causing the mass perhaps to be a little more opaque, but that indication is by no means strong enough to suit as a test of distinction between the two. When, on the contrary, alumina prevails in the combination, the mass is opaque and fat-like, although silica be present.

(f) It is necessary, therefore, to separate the constituents of such compounds before testing for either in $\ddot{H}B$; and the following is an excellent as well as simple method of doing this. Crush a fragment of the silicate to coarse powder on the agate slab with the (α) forceps, and then into the finest powder with a drop of water, between agates.‡ Wash the powder down into a capsule with a few more drops of water, and add a crystal, or if you have it in solution, a drop of phosphoric acid, and boil the whole to a syrupy fluid (which, if much alumina is present, will turn an earth color). Insoluble (in $\ddot{H}B$) phosphate of aluminum is thus formed, while the silica is not merely rendered soluble by the phosphoric acid, but gives that up in a free state to the $\ddot{H}B$ bead under O.P., which thus, on getting quite cool, gives the beautiful opaline reaction of $\ddot{H}P$,§ when a trace of the syrup is treated on the $\ddot{H}B$ for a considerable time in O.P.

(g) A still quicker and more perfect way of separating Si from Al_2O_3 is to heat the fragment of the combined earths (say, for instance, pure *Cyanite*) in O.P. on a roasting hook, till it glows brightly: then crush it as above, and grind into a paste with a drop of strong solution of boric acid, made by boiling a few crystals in a drop or two of water; wash this paste down into the capsule containing the $\ddot{H}B$ solution with a few drops of water, and boil. The Si is rapidly

* Plattner, 4th edition, p. 468.

† Paragraph (129, a).

‡ Vide Paragraph (141, c).

§ Paragraph (137, IX. r).

dissolved, leaving the Al_2O_3 at the bottom as a muddy powder. The solution (α) is decanted on to one agate, and the powder (β) well washed with water, ignited on a platinum spatula, and placed on the other. (α) tested in $\ddot{\text{H}}\ddot{\text{B}}$, gives at first a slight opalescence, but rapidly dissolves (until about 50 per cent. of the bead has been added) to a clear vitreous glass, not nearly so fluid as that of pure $\ddot{\text{H}}\ddot{\text{B}}$, which is due to Si , as is proved by the production of the same effect with pure silica. (β) gives the fat-like masses of pure alumina.

(h) Quicklime added to the (α) bead forms at first a clear ball in O.P. with considerable evolution of gas (oxygen?), but after some treatment a cloudiness forms round the ball (due to the separation of $\ddot{\text{H}}\ddot{\text{P}}$), which still remains clear, but some minute opaque balls of silico-borate of calcium appear to be disengaged from it.

(i) For the most rapid method of detecting a small proportion of Al_2O_3 in silicates containing little or no lime, as, e. g. *Adular*, *vide* Paragraph (251). A silicate which fuses on edge under O.P., and thus gives a blue glass on that part with Co solution (for which purpose the best support is the aluminum spoon), is sure to contain either an alkali or alkaline earth; probably both. The latter, if present, detects the alumina,* and is itself detected by its ball formation. If the former be potash, the green $\ddot{\text{H}}\ddot{\text{B}}$ pyrochrome is heightened in tint, and at once determined by vesiculation (216, a). If lithia, it is detected according to Paragraph (223).

(j) If pure silica, as *Tabasheer*, be boiled in a strong solution of $\ddot{\text{H}}\ddot{\text{P}}$, as described in (f), and the syrupy residue added by degrees to an $\ddot{\text{H}}\ddot{\text{B}}$ bead in H.P., it seems to dissolve to the extent of 100 per cent., or in equal parts, and on cooling assumes a most beautiful representation of the noble opal, reddish-yellow by transmitted light, cerulean blue by reflected; and this charming bead, having, if carefully made, such a large proportion of silica from the burning away of both $\ddot{\text{H}}\ddot{\text{B}}$ and $\ddot{\text{H}}\ddot{\text{P}}$, will keep without injury from atmospheric moisture. Its colors are not seen by gaslight.

(k) Calcic silicate affords balls in $\ddot{\text{H}}\ddot{\text{B}}$, opaque, white, but with a slightly vitreous (not fat-like) appearance, which emit a quantity of opaline matter into the first and fresh beads, until the silica is separated; but where there is still a little SiO_2 left, or if lime with a small quantity of silica be thus treated, balls, nearly transparent, appear, showing against the light curious transparent marks, shaped like those in Arabic writing, or those seen on "graphic granite;" these are seemingly prismatic crystals, but are at any rate the most delicate test I know of, for a minute trace of silica.

(l) *Wollastonite*, crushed and boiled with $\ddot{\text{H}}\ddot{\text{B}}$ as described in (g), affords

* *Vide* Paragraph (251).

(a) a syrupy solution, smelling of starch, (b) a thick yellowish-white sediment. (a) should be rapidly decanted from (b), which is well washed and boiled in water. When (a) is then separately boiled another sediment appears, with a greyish-white tint (c); it is extremely light, and takes a considerable time to settle in fresh water. When (b) has been extracted, heated in O.P. (when it glows = lime), and treated in $\ddot{H}\ddot{B}$, it gives the balls with grammatic crystals, characteristic of a calcic silicate of the second class, with masses of free silica. (a) in $\ddot{H}\ddot{B}$ gives no indication of lime; but the opalescent matter derived from silica in the second class (c), affords a few small balls of the second class of calcic silicate, with a large quantity of free silica in both first and second classes of condition. A partial decomposition of *Wollastonite* has evidently thus been brought about previous to treatment in $\ddot{H}\ddot{B}$ under O.P. Compare this with Paragraph (228, c).

[*Note*.—Quite forgetting I had gone through the above operation three weeks before, and described it in the MS. left with the publisher,* I did it again to-day (March 24, 1874), and as the two descriptions differ in one or two points, I shall let them *both* stand.]

(219). CERIUM, *Cerites*.

This oxide is classed along with Silicon for the following reasons: (a) Powder of pure *Cerite* affords, among other things, in an $\ddot{H}\ddot{B}$ bead under O.P., red-brown† balls, which are proved to contain the three earths, Cerium, Didymium, and Lanthanum. (b) Ceric oxide, made by O.P. from the so-called oxalate of cerium, or that purchased as "pure ceric oxide," produces precisely similar balls, proved by the spectroscope to contain Didymium. (c) Both of the above descriptions of balls are rendered opaque and yellowish by H.P. (a circumstance which caused me at first to attribute the balls remaining opaque to the separation of lanthanum); red-brown and transparent again by O.P.; and by repeated refining in fresh $\ddot{H}\ddot{B}$ bead these are rendered cloudy by the emission into them from the ball of an opaline matter, which is clear while hot. (d) What has been separated by the chemists as sulphate of didymium, affords balls in $\ddot{H}\ddot{B}$, not nearly so brown as the first, and becoming, by refinement in two or three fresh $\ddot{H}\ddot{B}$ beads, a pale violetish-red. (e) In all these cases the opaline matter given off was obtained, on dissolving the bead in boiling water, as an orange flocculent precipitate, which could be separated from any $\ddot{H}\ddot{B}$ by repeated boiling and decanting fresh water with it, the balls being of course insoluble. (f) In case (d) the pale violetish-red or strawberry-colored ball stopped emitting the opaline matter as it lost its brown tinge, and could no longer be made opaque in H.P., but just before doing so, curious transparent crystalline lines, like those on "graphic granite," were

* Paragraph (228, c).

† 2·1, Pl. III.

observed by transmitted light on its surface, after the disappearance of which, the pale strawberry-colored ball became perfectly clear, with a smooth surface. (g) Now this is exactly the behaviour of *silicate of lime* in $\text{H}\beta$,* with the single exception that the opaline matter given off by the latter ball into the bead is obtained by boiling as a white (not an orange) flocculent precipitate; but the lime-ball (which is of course colorless) has the same grammatic-looking crystals over its surface just before becoming quite pure.

(a) I therefore venture to suppose that the union between these three "earths" is chemical, not mechanical (as, indeed, might be also imagined from the difficulty of separating them), and that the combination should be termed "a Ceriate of Didymium and Lanthanum." (Type: *Cerite*.)†

OXIDES WHICH FLUX BORIC AND SILICIC ACIDS.

(220). The ALKALIES.

These are easily detected in the following way, even when present in the subject of examination in very minute quantity. A speck of cobalt oxide, about the size of a small pin's head, is taken up on a hot $\text{H}\beta$ glass, and treated in O.P. until it congests into a contained ball, which is easily manipulated (as it moves round the glass under O.P.) so that it remains on one side. Some of the very finely powdered essay is now attached to the hot glass on the side where the ball is, and fused in O.P. The slightest trace of alkali, and only of an alkali, will attack the ball, and cause a pink suffusion round it when the glass is cold; easily observed through a lens. Or the two operations may be performed in one by grinding the cobalt oxide and the subject of examination together with a drop of water between agates; and this is perhaps a better as well as quicker method, because any quantity of cobalt oxide may be taken, as only some of the balls formed will be suffused, according to the quantity of alkali present.

(a) The cause is apparently ascribable to the solution of a portion (the surface) of the borate of cobalt ball by the sub-alkaline borate formed round it. The proportion of *combined* boric acid which is able to dissolve the cobalt borate ball is 95 per cent., as may be proved by adding 5 per cent. of alkali to the glass, and treating with O.P., when all the cobalt borate balls will be dissolved, and a bead formed, blue hot, but pink on cooling. About 23 per cent. of alkali will cause the bead to remain blue on cooling. (Type: any *Alkali*.)

(b) A good method of detecting and distinguishing between the three alkalies when in combination is the following. Fuse the dry essay, ground to

* Paragraph (213, k).

† H. Rose says of Ceric oxide (French translation, p. 47, vol. i.), "Les dissolutions cériques neutres rougissent le papier de tournesol."

fine powder (not paste) with the agates, and placed between layers of pure lead in a keyhole mortar on aluminum plate* under O.P., until a copious fume or halo is spread on the plate. Scrape off some of the white or upper border of this sublimate gently with a penknife, so as not to scratch the aluminum, and treat a little of it in an $\text{H}\ddot{\text{B}}$ glass under O.P. The alkalies here, strange to say, form balls, clear hot, but white and opaque cold, while the ordinarily ball-forming alkaline earths do not. Of these, the potassic balls are easiest dissipated and dissolved in the glass; next the sodic, and lastly, the lithic; the reason apparently being that the strongest alkali soonest forms an alkaline borate which dissolves the balls, for if fresh alkali of any kind be added to either glass, these are at once dissipated. Of the constitution and formation of the balls themselves, the following seems a rational explanation. The fluid lead is sublimated under O.P., as plumbic acid, which combines with the alkali, forming alkaline plumbate, accompanied, of course, by a quantity of ordinary lead sublimate. The salt is at first fused without being dissolved, in the plumborate glass, by combining with a proportion of $\text{H}\ddot{\text{B}}$, forming alkaline plumborate balls, which are decomposed by the formation of an alkaline borate under further heat, as above described.

(c) The alkalies fused *per se* on aluminum plate, afford a copious white sublimate, which is distinguished, and can be separated from that of volatile metals by its extreme solubility in a drop or two even, of water.

(221). POTASSIDES.

With the exception of nitre, few inorganic substances contain much potash, while, on the other hand, it forms a trifling constituent of a considerable number of minerals, sometimes in as large proportion as 10 per cent.; and in these it is both interesting and important to detect this alkali. The pyrological means of detecting potash in presence of soda or lithia, or both, were formerly exceedingly unsatisfactory. The "flame" test for potash, i. e. the violet pyrochrome, is of little use, for two reasons. (a) The O.P. produced from a candle or oil lamp has a violet color itself, very like that afforded by potash;† as has, also, charcoal moistened with water, and some other substances. (b) It is entirely concealed by the orange pyrochrome of 1 per cent. of soda. The blue glass proposed by Cartmell for the purpose of absorbing the orange rays does not answer the purpose satisfactorily, as is evident from the description in Plattner.‡ The nickel oxide method, suggested by Lampadius, and brought forward again by Harkort, is described by Berzelius§ as being an admirable one; so that I ascribed my inability to use it successfully, to my own clumsiness, until I was

* Paragraph (93).

† Melted candle composition burns, affording this violet flame, by directing a pyrocone down upon it.

‡ Page 157, *et seq.*

§ Page 49, American translation.

consoled by reading, in Plattner,* "This test is applicable only when the substance contains a *very large* amount of potash."

(a) The following is a rapid and certain way of detecting the most minute trace of potash, even in a soda salt, as, e. g. sodic carbonate. If you have a table pyrogene, you can use a hand one with the platinum jet taken off, or one having a vesiculating jet.† If you have only the mouth pyrogene, you must first use it to dissolve as much as possible a trace of the powdered substance previously proved to contain an alkali‡ in an $\ddot{H}\ddot{B}$ bead; then, rapidly removing both the bead and the pyrogene from the gas lamp or candle, blow into the former while still red hot with the latter, by advancing the platinum jet to the ring of the wire.§ The vesicle produced should be breathed upon at once, and the bluish-white cloud which forms (unless soda only is present in sufficient proportion to form borax) brought near the flame of a spirit lamp. If the cloud is due to potash, it will vanish at once, leaving the vesicle smooth and round; if it be merely the $\ddot{H}\ddot{B}$ cloud (which, however, is whiter than that formed by potash), the vesicle will shrivel up with the heat before the cloud vanishes. With a large orifice in the jet of the pyrogene, vesiculation is an easy matter, and never fails, but with the common jet requires some dexterity and practice to perform.

(b) Potassic carbonate fused with pure lead in a keyhole mortar on aluminum plate,|| affords a sublimate, which slowly dissolves in $\ddot{H}\ddot{B}$ with evolution of many bubbles, and when these are gone, takes the shape of smooth white opaque balls; these under continued O.P. also dissolve, forming first irregular semitransparent fragments, which finally disappear, leaving a glass clear but little refractive. Potash may thus be distinguished and separated from soda, the plumborate balls of which neither form fragments in dissolution nor disappear nearly so quickly.¶ As neither lead oxide nor potash alone behave in this way in $\ddot{H}\ddot{B}$, it seems evident that their combination, thus effected, is chemical, and that of this, potassium forms the base, plumbic oxide the acid constituent.

(c) Sulphates containing potash, as, e. g. *Alunite*, seem to afford the violet pyrochrome of KO very strongly when heated in H.P. on a steel spatula, and moistened with water, a phenomenon no doubt arising from a partial decomposition of the salt, as there is a slight formation of ferric sulphate.

(d) Potash has the curious property, when added from a mere trace to the extent of about 10 per cent. to $\ddot{H}\ddot{B}$ under O.P., of intensifying the green pyrochrome of the latter, while its own pale violet pyrochrome entirely vanishes, but reappears after this addition, when the flux may be presumed to have an alkaline character, and the glass then smokes on removal from O.P. It may

* Page 156.

† Paragraph (81).

‡ Paragraph (215).

§ *vide* Paragraph (110).

|| Paragraph (216, b).

¶ Paragraph (222, a).

be thus easily distinguished from lithia. As KO thus heightens the green color of burning $\text{H}\ddot{\text{B}}$, I tried to detect the latter in *Tourmaline* by means of it, but got only a greenish-yellow from the soda also present in that mineral, but I nevertheless believe from this circumstance that in Turner's test it is potassic borate, not "fluoride of boron," which burns with a green color.

(222). SODIDES.

The difficulty of detecting soda in minerals, &c., seems paradoxical, as it arises from the "fatal facility" with which its orange pyrochrome is produced by almost every inorganic substance when strongly heated. A fragment of calcic or magnesian carbonate, judging from the strong orange pyrochrome in O.P., would appear to be full of soda, and yet we know that what is burning is carbonic acid and water, for the color ceases entirely when those have been expelled, and the fragment has become "quick," or caustic, or dehydrated. Some contrivance, therefore, seems necessary, by which this very delicate indication (which soda, not sodium,* no doubt affords with more intensity than any other substance) may be utilized, so as to betray the presence of that alkali only when a chemical analysis shows it to be really present.

(a) Such an effect is admirably rendered by the green pyrochrome of boric acid; for, as we have seen,† alkalies alone are perfectly soluble by fusion in that reagent, so that we at once, by using it, get rid of the troublesome manner in which the alkaline earths, various oxides, and silica, alumina, &c., afford the orange pyrochrome; and we have the field of detection, therefore, immensely narrowed, by confining it to the three alkalies found in nature—potash, soda, and lithia. Of these, the effect of adding the first is only to heighten the green color, rendering it bluish-green and more vivid.‡ The third, when added in considerable quantity, produces, especially in H.P., strange to say, the exact violet tint of pure potash burning. On addition of the merest trace of soda to the $\text{H}\ddot{\text{B}}$ thus saturated with nitre and lithic carbonate, the violet tint vanishes, except in a good H.P., and what now appears is a greenish-orange; if the same amount of soda had been added to the pure $\text{H}\ddot{\text{B}}$ bead, the resulting pyrochrome would have been a pale yellow-green. About 2·5 per cent. of the $\text{H}\ddot{\text{B}}$ bead in soda extinguishes the green, and shows us only an orange pyrochrome. (Type: *Adular*.) A confirmatory test for soda in presence of potash, by which it may be also quantitatively separated from that, can be applied by fusing the essay with lead, and treating the resulting sublimate in $\text{H}\ddot{\text{B}}$.§ The sodic plumborate balls are less easily dissipated than the potassic

* If a fragment of sodium be rapidly taken up on a hot $\text{H}\ddot{\text{B}}$ bead, and plunged at once into a good H.P., little or no orange pyrochrome is obtained, and the metal becomes a black mass.

† Paragraph (215).

‡ *Vide* Paragraph (216, c).

§ Paragraph (217, b).

balls, and may be extracted from the HB matrix by boiling water after those are dissolved.

(223). LITHIDES.

Lithia existing to the extent of 2 or 3 per cent., as in *Petalite*, is easily detected as in (139, XI. c), when the red-violet pyrochrome is so strong that it is presumed 1· or even ·5 of lithia could also be detected by the E.P. The only substance with which the reaction could at all confound it, is strontia, although, by the way, the pyrochrome of the latter has an orange tinge, which that of lithia has not, but the application of a trace of the substance to an HB bead in O.P. would at once settle this point.

(a) Lithia has the curious effect of affording a pale violet pyrochrome precisely like that of potash fused *per se*, when treated in HB by O.P., while potash similarly treated only heightens the green one.* These two alkalies, therefore, which might be confounded when the LiO is in very small, or the KO in large proportion, can thus be easily distinguished, as also by vesiculation.†

(b) Lithic carbonate fused with pure lead‡ affords a sublimate which gives in HB beautiful smooth opaque white balls, which may be observed with the lens to be clear for a considerable time in the hot glass. Lithia is thus well distinguished from the other two alkalies in combination, for its plumborate balls are not nearly so soon dissipated by O.P. The green pyrochrome of HB is not sensibly altered in this glass; if anything, it is heightened, so that the reaction (a) does not hold good here.

OXIDES WHICH FORM CLEAR BALLS IN HB WHEN TREATED IN IT UNDER O.P.

(224). THE ALKALINE EARTHS, DIDYMIUM, LANTHANUM, MANGANESE, AND CADMIUM.

No reaction in pyrology is more marked and decisive than the interesting property possessed by the above oxides (which was discovered by myself, at Simla, India, on the 9th of July, 1869), of forming balls or globules inside of an HB bead, when a minute portion of the powdered or fragmental oxide is applied to that under O.P. The globules are of two kinds: (a) clear, that is, transparent, whether colored or achromatic; and (b) opaque, whether colored, or black, or white. In most cases, the balls when first formed are opaque, and become clear by the application of O.P., continued for a greater or longer time, evidently in proportion to some peculiarity in the nature of the oxide or oxides forming the ball. Thus, pure quicklime applied to HB under O.P., forms an opaque white ball only for a second, and even to obtain that, the O.P. should be directed on the side of the bead away from the fragment of lime. Suppose this result obtained,

* Paragraphs (216, c), and (217, a).

† *Vide* (216, a).

‡ Paragraph (216, b).

we see even without a lens, the $\text{H}\ddot{\text{B}}$ bead a beautifully transparent ellipsoid with a white opaque sphere or ball floating in it. On treating this for a single second with the point of the O.P., the opaque white ball flashes or glows with a yellowish phosphorescent light, and seems at first to have disappeared into the bead, but with the lens we observe it, apparently with exactly the same diameter as before, but now, not merely transparent and achromatic, but evidently of a more refractive nature than the containing bead. The bead or containing glass, however, is no longer perfectly clear; a slight opaline cloud or streak, evidently given off by the ball in becoming transparent, is now suspended in it. If, instead of quicklime, we use a fragment of lime hydrate, we find the resulting opaque white ball takes much longer time to clarify by O.P., and that, when it does become clear, the opaline matter given off by it, is very considerably increased.

(a) If we apply a fragment of pure *Calcite** to the bottom of an $\text{H}\ddot{\text{B}}$ bead, and apply O.P. to it, the strong orange pyrochrome (which affords the lines (D) in the spectroscope) is emitted, while the fragment gradually glows with a whiter light, and the orange light becomes proportionally fainter; but the moment white light is produced, and not a moment before, the orange pyrochrome ceases; the fragment combines with the $\text{H}\ddot{\text{B}}$ bead, and in doing so, a bubble or two of gas bursts out of the latter, which examined through the lens, shows the lime borate formed as a white opaque ball, which is clarified by O.P. as above described. Thus it seems impossible to doubt (a) that the orange light is emitted from calcic carbonate in this condition in the inverse ratio to its causticity or absence of CO_2 . But a drop of distilled water added to the fragment in the above position before it has quite ceased to emit the orange light, brings that back as strongly as ever in O.P. again, and a piece of calcic hydrate behaves in the same way, therefore the strength or quantity of emission of the orange light from calcic carbonate in this condition, seems directly proportional to the quantity of water it contains.

(b) The opaline matter (223) given off by the lime borate ball into the $\text{H}\ddot{\text{B}}$ bead was at first supposed by me (and this opinion has been published†) to be due to the lime itself; but although perhaps not impossible, it was most improbable that the *same* lime should, under the *same* conditions, afford in the *same* boric acid such very different reactions as a borate ball, and a suffusion of opaline matter. But I found by the average of five assays, that the weight of the lime borate ball (extracted by boiling water) was a *constant multiple* of the

* The specimen from which these results are taken can be proved to be absolutely pure carbonate of lime.

† 'Proceedings of the Royal Society,' vol. xx., p. 463, paragraph 64. I was upheld in this opinion by an eminent authority.

weight of the calcined lime taken to make it, and that this multiple was 4·5. Thus, if W = the weight of the ball, the formula $\frac{W}{4\cdot5}$ invariably gave within ·2 or ·3 of the quantity of lime in it, or about 22 per cent., and with considerable difficulty, by carefully avoiding O.P., and using a very moderate degree of heat, I once managed to combine a weighed lime carbonate fragment with the $\text{H}\ddot{\text{B}}$ bead *without* calcining the former, when, with much effervescence, so much opaline matter was emitted, that the bead became opaque on cooling; but the weight of the extracted ball now indicated, instead of a loss, as the quantity of opaline matter might have suggested, 40 per cent. of lime, an excess of nearly double, which exactly corresponded with the weight of volatile matter which would have been driven off by calcination. In other words, the weight of the extracted ball was the multiple 4·5 of the lime taken, *if that had been duly calcined*. Surely it seems only a fair conclusion from this experiment, that the opaline matter was due either to the CO_2 expelled, or to water combined with it; and, as the former is a gas which was seen escaping from the $\text{H}\ddot{\text{B}}$ in bubbles, that it must be due to the latter?

(c) The above account seems more suitable to quantitative than to qualitative pyranalysis; but as this opaline matter is henceforth attributed in this work to combined water, it was necessary to give in full the reasons for such attribution, of which another is also given in the Introduction,* where it is shown that the mere fusion of $\text{H}\ddot{\text{B}}$ on a large surface of new and clear platinum gives rise to this opalescence, which in that case could not be possibly due to anything but some compound of H. and O.

(d) The formation of these balls in $\text{H}\ddot{\text{B}}$ is, therefore, here supposed to be due to the chemical replacement of a proportion of combined water in the oxide, by its equivalent or boric acid, and it is also assumed that this proportion is regulated by the capability of the oxide to thus give up more or less of this combined water. When the oxide can be rendered nearly anhydrous, as in the case of lime, the boric acid of the lime borate ball is in large proportion (78 per cent.), and the borate is then clear, and, unlike fused boric acid, absolutely insoluble in boiling water, and further, so hard as to scratch glass. The borate thus formed is quite as fusible as, though utterly insoluble in, the boric acid bead, and being in much smaller quantity than the latter, assumes on the application of sufficient heat to fuse both, the spherical shape, by the same natural law which forces the other to assume it, so that we have thus a sphere within a sphere, for the bead would be spherical if the attraction of the wire did not preserve it an ellipsoid. Briefly, the production of contained balls by the

* Paragraph (15).

application of some oxides to $\text{H}\ddot{\text{B}}$ under O.P. is here supposed to be due to the formation of fusible borates containing less water than fused boric acid (which, as will be seen,* is by no means anhydrous), and *consequently* insoluble in it under O.P.

(e) Another property of two of the alkaline earths (Strontia and Lime) which distinguishes them from other oxides, is seen in the fact that, when held in the candle H.P. they remain perfectly white, while other "earths," especially silica and alumina, become more or less black in the same position; and this is to some extent the case even when they are held in the flame of a spirit lamp, in which alumina is completely, and silica partly, blackened, but lime and strontia not at all. The last-named oxides also have the power, when rendered quick or caustic by heat, of dehydrating cobalt hydrate, changing it from pink to blue, and these two rapid but certain indications may be put in force by the geologist or mineralogist in the field on the spot where he suspects a limestone to exist, if he carries in his pockets a spirit lamp,† a piece of platinum wire, and a small bottle of cobalt solution, without which, at least, he should never travel.

(225). STRONTIANIDES.

Besides the similarity of its intensely red pyrochrome to that of Lithia (in which, however, unless due to calcic impurity in the specimen, a tinge of orange, not seen in the other, is visible), Strontia seems connected with it, by the high state of causticity to which mere heating brings it, in which probably no earth comes near it, except lime, from which it is easily distinguished by the violetish tinge of its red pyrochrome ($\text{H}\ddot{\text{S}}$, with a tinge of orange) even in E.P., where the lime pyrochrome almost equals in volume and intensity the strontian one. In $\text{H}\ddot{\text{B}}$ strontia gives a borate ball almost identical with that of lime, though bubbles are raised in the former by O.P., and it emits more opaline matter than the latter, but strontia being so rare, it is seldom necessary to determine its quantity accurately.

(a) If the mineral *Aragonite*, which decrepitates, be ground to a paste between agates and held in a candle E.P., the small quantity of strontia present is very clearly denoted, by the bluish-red tint at the under side of the base of the pyrocone, while the apex shows the brilliant red-orange (C) of lime. (Type: *Celestine*.)

(226). CALCIDES.

Lime is, perhaps next to iron, the most important inorganic substance

* *Vide* Paragraph (229), Magnesia.

† I once tested a limestone in the Himalaya in this way, with my brandy-flask, in the neck of which I poised, by wrapping cord round it, a piece of a tobacco-pipe, with strings passed through it, into the brandy.

to man in the world. Without houses, or with houses built of brick or stone without mortar; without bridges, road or rail ways, harbours, lighthouses, tunnels, &c., we should, indeed, on this earth, be little better than monkeys, from whom, according to some, we are descended; for in that wretched case we could have no better habitation than the hollowed trunks of trees. We cannot, therefore, be too careful in noting any characteristic reactions of this all-important substance. As may be easily learned by reference to Plattner, Berzelius, Scheerer, Von Kobell, or any of the best authorities on blowpipe analysis, the determination of lime in minerals, &c., is all but excluded from that, and the student is recommended, instead, to resort to "the wet way."

(a) Now, however, lime, and the alkaline earths, can be pyrognostically detected far more certainly, rapidly, and delicately than by the wet, or any other analytical process, except the spectroscope, and there is some reason to doubt the correctness of its results on this point, as will be presently seen.* If we make a bead or glass of pure crystallized $\text{H}\ddot{\text{B}}$, and examine it carefully through a powerful lens, we find in it, (a) round air bubbles, for these can never be altogether expelled; but only the merest tyro could mistake them for transparent contained balls; † the surface of the former reflects the light from windows, &c., through the bead (a curious fact, as the air within them is transparent), while that of the latter does not; (b) a few small opaque and semiopaque specks, apparently derived from dust in the room; and (c) that these specks, though all amorphous, are, some semitransparent (silica), and some white and fat-like (alumina). If now we take up on such a bead, made red hot, about a square half inch of clean white chemical filter-paper from a laboratory, and treat the other side of the bead with O.P., the paper burns; the carbon is soon volatilized into CO_2 , and the inorganic residue, whatever it may be, enveloped in the bead. A piece of an unused filter that size which I tried, in $\text{H}\ddot{\text{B}}$, on which it had been taken up and treated in O.P. showed (d) minute semitransparent balls with grammatic crystals, ‡ indicating silicate of lime; (e) one or two balls, however, were white and waxy on the surface, § showing the presence of lime with a little alumina; (f) the green pyrochrome of the $\text{H}\ddot{\text{B}}$ was slightly orange—soda; || (g) after further O.P.,

* This doubt may perhaps be better detailed here. If we heat a weighed fragment of calcic silicate, as, e. g. *Wollastonite*, in O.P. with a drop of hydrochloric acid, the spectroscope will show the characteristic line (Ca α) of calcium. HCl is considered absolutely necessary for this reaction (*vide* Roscoe, Sp. Anal. p. 77), but the line may also be obtained with equal distinctness by merely treating the fragment in E.P.—Paragraph (144)—and the fragment is thus *not* decomposed. Lime is *infusible*, even in O.P., far less in E.P., and I have found that the weighed fragment of calcined *Wollastonite*, after affording in E.P. the red-orange line (Ca α) for half an hour, has the same weight as at first! The red line, therefore, could not possibly be due to the combustion of lime, and a natural conclusion seems, that it is due to a *partial decomposition of the hydrocarbonous pyrocone by the causticized lime*.

† Paragraph (219). ‡ Paragraph (213, 4). § Paragraph (252, a). || Paragraph (217, a).

calcic carbonate, placing this over that on aluminum plate, in a powerful O.P., until the ball seems quite fluid or nearly so. If an H.P. be then applied, and the ball left to cool on the aluminum, any lime present will show itself by curious raised circular crystallizations over the surface of that part where it has remained; while the surface of magnesian soda cools smooth, or having only the usual plane facets of fused soda.* In the essay of *Dolomite*, the magnesian part seems utterly undissolved, swelling out from the bead in round masses, which have a smooth surface; the calcic part, which is found *next* the pyrocone, exhibits the above-mentioned raised crystals, like small round maggots.

(d) The pyrological examination of a calcialuminic silicate is sometimes a rather complicated affair, and, as in the manufacture of mortars, whether hydraulic or pneumatic, especially the former, it is not so much the quantity or quality of the lime the examiner has to attend to, as the conditions under which it is combined with the aluminic silicate in the limestone, mineral reactions are, for once, more important than analytical ones, and I hope, therefore, the following account of the behaviour of various limestones and artificial mortars, &c., pyrologically, will be interesting, at least to the engineer or architect, if not to the chemist; entreating him to pay particular attention, in the first place, to the *waxy appearance* of an uncrystallized limestone, which is a sure indication of its richness.† In this way I suspected (and afterwards proved) a specimen, labelled "chert," in a geological cabinet, to be nearly pure calcic carbonate. The first four mentioned specimens are placed in their (English) geological, descending order. The following is a table of the comparative *glowing* of a fragment of the mineral in O.P.:

- (i.) White hot, intensely luminous = pure Lime.
- (ii.) White hot, with yellowish tinge = Platinum.
- (iii.) Whitish-yellow = (a) *Dolomite*, (b) *Wollastonite*.

And of the comparative *slaking* with water when cold:

- (a) Disintegrates with violence and steam = pure Lime.
- (β) A slight commotion; no disintegration = *Lias*.
- (γ) No change = *Kunkur*.

My object here is to enable the practical experimenter to select, from the various types given, a limestone, or mortar, concrete, &c., which, as he can thus ascertain by a few rapid and simple experiments, will be suitable for his purpose, whether that be to "set" under water, or in the atmosphere.

(e) *Portland Stone* (granular, oolitic appearance).—This mineral glows = (i.) in O.P.; gives the reactions of a *pure* calcic carbonate‡ with free H₂, and has, therefore, little interest here.

* Paragraph (118, c).

† Paragraph (128, e, d).

‡ Paragraph (221, b).

the silica from (d) was separated as opaline matter into the bead,* rendering it nearly opaline on cooling; the alumina from (e) was also diffused, and the clear lime borate balls collected into one larger one, which had a greenish-yellow tinge (FeO) 1.9. The bead, vesiculated and breathed on,† gave a strong potash reaction. There were thus, in this half inch of chemical filter-paper, lime, silica, alumina, iron, soda, and potash. The minute specks (b), only seen through the lens with difficulty, were far too small to have produced any of the ulterior results.

(b) In testing for lime in a mineral, other than a phosphate, after the proof by carbonization and cobalt solution,‡ and the proof by E.P.§ that the chief reacting oxide is lime, and not strontia, a well-calcined fragment, the size of a pin's head,|| should be taken on the hot $\text{H}\ddot{\text{B}}$ bead and attentively observed while under O.P. If it glows with a sudden phosphorescent flash in combining, and is then seen by the lens to be a nearly clear ball, and if, the bead being again treated in O.P., the clear ball is transparent while red hot, the essay may be presumed to be pure calcic carbonate or sulphate; but the latter evolves much more gas in combining with $\text{H}\ddot{\text{B}}$. If, however, the ball is *opaque* while red hot, the presence of magnesia or baryta may be suspected. The latter impurity is easily detected in many ways. (a) The clear ball in $\text{H}\ddot{\text{B}}$ will, under a strong O.P., rapidly decompose, until the baryta is spread as a white suffusion over the bead. (b) If in any considerable quantity, as, e.g. in *Barytocalcite*, BaO gives a yellowish-green pyrochrome in O.P., while the lime affords its brilliant Red orange in E. P. (c) A drop of Mn. solution, heated on the fragment in O.P., turns green in presence of BaO. Magnesia is not so easily detected in a limestone. If, however, by negative results to the above baryta tests, its presence is concluded,¶ boil some of the powdered mineral with some $\text{H}\ddot{\text{B}}$ crystals in the water, and treat the residue (a white powder) in a fresh $\text{H}\ddot{\text{B}}$ bead with O.P. The magnesia will no longer form balls, but is spread over the bead as a white suffusion; the lime forms balls, which are no longer opaque when red hot. The MgO may be collected from its suffused state in the bead, by boiling that in water, when it settles as a white residue, which is washed by repeated boilings and decantations, and tested in $\text{H}\ddot{\text{B}}$ for magnesia.** The Co. solution test is of no use here, because the lime utterly conceals the MgO pink in O.P., turning the cobalt hydrate black.

(c) One of the most rapid as well as the best methods for distinguishing between lime and magnesia, and that, too, in the presence of metallic oxides, is to fuse some of the finely-ground essay with a fragment three times its bulk of pure

* Paragraph (213, h). † Paragraph (216, a). ‡ Paragraph (219, e). § Paragraph (139).

|| This is easily procured, by calcining a large fragment in a platinum hook in O.P., and then crushing it on the agate slab with a platinum or steel spatula, into smaller ones.

¶ *Vide post*, Paragraph (228, b).

** Paragraph (228, a).

sodic carbonate, placing this over that on aluminum plate, in a powerful O.P., until the ball seems quite fluid or nearly so. If an H.P. be then applied, and the ball left to cool on the aluminum, any lime present will show itself by curious raised circular crystallizations over the surface of that part where it has remained; while the surface of magnesian soda cools smooth, or having only the usual plane facets of fused soda.* In the essay of *Dolomite*, the magnesian part seems utterly undissolved, swelling out from the bead in round masses, which have a smooth surface; the calcic part, which is found *next* the pyrocone, exhibits the above-mentioned raised crystals, like small round maggots.

(d) The pyrological examination of a calcialuminic silicate is sometimes a rather complicated affair, and, as in the manufacture of mortars, whether hydraulic or pneumatic, especially the former, it is not so much the quantity or quality of the lime the examiner has to attend to, as the conditions under which it is combined with the aluminic silicate in the limestone, mineral reactions are, for once, more important than analytical ones, and I hope, therefore, the following account of the behaviour of various limestones and artificial mortars, &c., pyrologically, will be interesting, at least to the engineer or architect, if not to the chemist; entreating him to pay particular attention, in the first place, to the *waxy appearance* of an uncrystallized limestone, which is a sure indication of its richness.† In this way I suspected (and afterwards proved) a specimen, labelled "chert," in a geological cabinet, to be nearly pure calcic carbonate. The first four mentioned specimens are placed in their (English) geological, descending order. The following is a table of the comparative *glowing* of a fragment of the mineral in O.P.:

- (i.) White hot, intensely luminous = pure Lime.
- (ii.) White hot, with yellowish tinge = Platinum.
- (iii.) Whitish-yellow = (a) *Dolomite*, (b) *Wollastonite*.

And of the comparative *slaking* with water when cold:

- (a) Disintegrates with violence and steam = pure Lime.
- (β) A slight commotion; no disintegration = *Lias*.
- (γ) No change = *Kunkur*.

My object here is to enable the practical experimenter to select, from the various types given, a limestone, or mortar, concrete, &c., which, as he can thus ascertain by a few rapid and simple experiments, will be suitable for his purpose, whether that be to "set" under water, or in the atmosphere.

(e) *Portland Stone* (granular, oolitic appearance).—This mineral glows = (i.) in O.P.; gives the reactions of a *pure* calcic carbonate‡ with free H⁺, and has, therefore, little interest here.

* Paragraph (118, c).

† Paragraph (128, e, d).

‡ Paragraph (221, b).

(*f*) *Lias* (dark iron-grey, waxy appearance).—(1) In O.P. glows = (ii.); turns brownish-yellow outside, but the inner fracture is white and limy. (2) In E.P. the pyrochrome = Ca (Plate I.). (3) With a drop of water slakes = (β), with argillaceous smell. (4) In $\ddot{H}\ddot{B}$ before O.P. forms a clear yellow-green ball, nearly green cold (a good deal of FeO), with little effervescence. (5) Opaque hot in O.P. (MgO, Si, or Al_2O_3), but no Si crystals. (6) Opaque in H.P. (Si or Al_2O_3 , no MgO). (7) In further O.P., copious opaline matter given off, and crystals of Si appeared on the surface of the ball.

(*g*) *Magnesian Limestone* (drab color, sugary appearance, soft and friable).—(1) In O.P. glows = (iii.); turns greenish-yellow outside, white inside. (2) In E.P., a slight (Ca) pyrochrome with rose tint (presence of magnesia). (3) In $\ddot{H}\ddot{B}$, a clear ball; yellow hot, pale yellow cold; little opaline matter given off (little Si or Ba). In O.P. opaque hot; in H.P. clear hot (MgO and Ca). After H.P., the cold bead not opaline (little or no Si). (4) On aluminum foil with soda, fused to an opaque bluish-grey mass, with a few round crystals (CaO and MgO). No black stain or hepatic smell (no sulphur or SO_3). This mineral, therefore, appears to consist chiefly of Lime and Magnesia, with a trace of Iron protoxide.

(*h*) *Mountain Limestone* (brownish-grey: compact, waxy).—(1) O.P. infusible on edge (little or no Si) glows = (i.). (2) In E.P. (C) pyrochrome with rose tint at base of pyrocone (a little MgO). (3) In $\ddot{H}\ddot{B}$ not much effervescence (taken in conjunction with the fact of the essay glowing = (i.) in O.P. this fact indicates magnesia). A clear ball, colorless (no FeO); opaque hot in O.P. without giving off much opaline matter (MgO). (A Limestone with a little Magnesia.)

(*i*) Thus (*e*) (*f*) and (*g*) are calcic or magnesian calcic carbonates, too pure to be of much interest here, but are merely given as specimens of the rocks over and underlying the carboniferous system in England, that is, as shown in a geological cabinet; but (*f*), or the *lias*, is especially interesting, as forming the model (formerly) in England, of a good hydraulic mortar, though this specimen is certainly too rich for such a purpose; as indeed the *lias* must have been which Smeaton used for the Eddystone Lighthouse, for he burned it with *Pozzuolana* and *Trass*. The examples following are selected without reference to geological position.

(*j*) *Wollastonite** (white, tabular, splitting aciculary, like pure hematite).—(1) In O.P. slightly fused on edge (Si and Ca or an alkali) glows = (iii.). (2) In E.P. (Ca) pyrochrome, with a tinge of rose near the base of the pyrocone (calcic silicate, with a little Mg). (3) In $\ddot{H}\ddot{B}$ a small fragment fused with great difficulty to an opaque ball: the fine powder gave balls, some opaque, others

* *Vide* also Paragraph (218, *l*).

with grammatic crystals, and semitransparent (Si). (4) Green pyrochrome unaltered (no soda). From the above, it seems doubtful if *Wollastonite* such as this would, *per se*, make even a hydraulic cement.

(k) *A Septaria Nodule*, from Sheppy (buff color; compact, semiwaxy, stony).—(1) In O.P. glows = (ii.); turns greenish-brown, and fuses slightly on edge to a brown glass (Si and Fe_2O_3). (2) In E.P. strong (C) pyrochrome (Ca with little or no magnesia), slakes = (β) with argillaceous smell. (3) In $\text{H}\ddot{\text{B}}$, a fragment the size of a small pin's head fuses easily with effervescence, to a ball (little or no Mg) yellow hot, nearly colorless cold (a little FeO), opaque both in O.P. and H.P. (Si), giving off a moderate quantity of opaline matter. (4) The green $\text{H}\ddot{\text{B}}$ pyrochrome unchanged (no soda). (5) Vesiculated, gave a moderate KO reaction. (6) With a few specks of sodic carbonate the ball dissolved, and the whole bead was rendered opaque and porcelain-like.

(l) *Kunkur*, from the Agra District, India (greenish-yellow, semiwaxy, uncompact).—(1) In O.P. fuses easily on edge to a brown glass (presence of Si with Ca or an alkali, and Fe_2O_3); glows = (iii.). (2) In E.P. (Ca) pyrochrome with rose tint (lime and magnesia). (3) In $\text{H}\ddot{\text{B}}$ a fragment rapidly formed a ball, greenish-yellow (FeO), with Si crystals (not much Si) on surface, giving off a very large quantity of opaline matter with a porcelain appearance (a considerable quantity of Al_2O_3 and water, or phosphoric acid). The ball not quite round, but egg-shaped in H.P. (?). (4) The green pyrochrome unaltered (no soda). (5) Vesiculated and breathed on, gave moderate reaction for potash. (6) With a speck of soda, the ball at once attacked, giving off opaline matter; the whole bead shortly assumed a porcelain appearance. (7) With a speck of potassic carbonate, the opaline matter became blue and curdy, showing a large proportion of phosphoric acid.

(m) *Akbar's Mortar*, from Ruins at Secundra, India: 300 years old. [When Lord Lake was investing Agra, in 1801, he failed to disintegrate the stones and bricks held together with this mortar by blasting the buildings.] (Pinkish-white, compact, stony).—(1) In O.P. glows = (ii.); turns brown, and fuses on edge to a glass (Si, with Ca or an alkali). (2) In E.P. a strong (C) pyrochrome (little or no magnesia). (3) In $\text{H}\ddot{\text{B}}$ easily forms a very yellow ball, (Ca with about 2 per cent. of FeO), giving off a quantity of opaline matter. (4) Green pyrochrome unchanged (no soda). (5) Vesiculated, &c.; a moderately strong KO reaction. (6) With addition of a considerable trace (three or four specks) of soda, the ball was not attacked (a good deal of Si chemically combined with the lime).

(n) *Mortar from a House on Shooter's Hill, Kent* (pale buff color, with pebbles the size of a pin's head, conglomerated).—(1) In O.P. does not fuse or

turn color (little Si in combination); glows = (ii.). (2) In E.P. moderately strong (C) pyrochrome. (3) In $\ddot{H}\ddot{B}$ rapidly forms a clear ball, slightly yellow, with faint Si crystals, but masses of Si uncombined, floating in the bead. (4) Green pyrochrome unchanged (no soda). (5) Vesiculated, &c., slight KO reaction. (6) With a speck of soda, the ball rapidly disappeared, forming a porcelain bead (Al_2O_3 with the lime).

(o) *Portland Cement*, used as exterior "facing" for a house on Shooter's Hill, Kent (grey, with many pebbles conglomerated).—(1) In O.P. edge fused to brown glass (Si with Ca or alkali); glows = (ii.). (2) In E.P. a moderate (C) pyrochrome. (3) In $\ddot{H}\ddot{B}$ a piece without pebbles formed a yellowish ball rapidly: opaque hot both in O.P. and H.P. (4) The green pyrochrome increased (KO). (5) Vesiculated, &c., a strong KO reaction. (6) A speck of soda destroyed the ball, and rendered the whole bead porcelain.

(p) *Mortar from the New Agra Fort Barrack*, which cost 10,000*l.* in 1868 (a muddy-looking powder with roundish pieces of raw Kunkur in it).—(1) In E.P., a paste of the powder gave only an orange pyrochrome with a slight (Ca) tint (lime), and rose near the base (magnesia). (2) In $\ddot{H}\ddot{B}$ the powder forms a silicious mass of opaline matter with semitransparent fragments, and one or two minute yellowish balls, with crystals over the surface (calcic silicate, with iron). (3) The green pyrochrome made yellowish (.5 per cent. of the bead, soda).

(q) *Mortar from Eltham Palace Ruins*: 800 years old (whitish-yellow).—(1) In O.P. glows = (ii.) and shows many pebbles conglomerated. Does not fuse, but turns brownish (Fe_2O_3). (2) In E.P. a moderate (C) pyrochrome with rose tint (calcic silicate, with magnesia). (3) In $\ddot{H}\ddot{B}$, a greenish-yellow nearly opaque ball, with lumps of silica separate. (4) Green pyrochrome unchanged (no soda). (5) Vesiculated, &c., shows a faint trace of potash. (6) A speck of soda rendered the whole bead opaline and destroyed the ball.

(r) *Apatite* from a Freiberg cabinet (yellowish-green; glassy; crystalline).—(1) In O.P. glows = (iii.); does not fuse on edge, or only slightly. (With a lime mineral this shows little or no Si.) (2) In E.P., a moderately strong (C) pyrochrome: no rose tint. (These reactions show that there must be something, neither silica nor magnesia, combined with the lime.) (3) In $\ddot{H}\ddot{B}$, white, fat-like fragments, like alumina, utterly unchanged by the strongest gas O.P. [This is, to my knowledge, the only lime mineral, or even mineral containing lime, which does not afford balls in $\ddot{H}\ddot{B}$. As the presence of lime in considerable quantity was proved by (2), the operator, supposing he had to discover the composition of his essay, would have now concluded it to be calcic phosphate: the following proves the fact.] (4) Heated, and a drop of manganese solution (sulphate)

added, the steam smells strongly of phosphoric acid, while the fragment turns intensely black. (5) In H.P. after this treatment, the essay affords the lurid green pyrochrome of phosphoric acid, and white opaque balls in an $\ddot{H}\ddot{B}$ bead. (6) In an $\ddot{H}\ddot{B}$ glass under O.P. *Apatite* powder is rounded on the edges, and when the glass is collected as a *ringed bead** it fuses at once to white opaque balls. (7) K_2CO_3 fused in small quantity with (6) dissolves all fragments rapidly, but balls slowly to a glass, clear hot, but opalescing white on cooling. The quantity of K_2CO_3 taken to clarify this glass, shows approximately how much $\ddot{H}\ddot{P}$ *Apatite* possesses. If pure lime be added, there is no change in the glass, but pure magnesia at once forms insoluble roundish fragments of magnesian phosphate, and, consequently, causes the glass to remain clear on cooling.

(s) *Coprolite*, from Cambridgeshire.—In an $\ddot{H}\ddot{B}$ glass gives the reactions of *Apatite*, but forms opaque white balls more easily under O.P. This glass takes a considerable quantity of K_2CO_3 to clarify it, and shows a few small fragments of insoluble magnesian phosphate.

(t) *Sombrerite*, or Mineralized Guano, from the Island of Sombrero, South America.—Affords the *Apatite* reactions in an $\ddot{H}\ddot{B}$ glass, but leaves what appears an unaccountably large proportion of insoluble magnesian phosphate, but, on the further addition of K_2CO_3 , the glass becomes reddish and vitreous on cooling, an effect seemingly due to uric acid.†

(227). From the above examples we find that a specimen fragment of first-rate *air* mortar, especially when intended for a hot dry climate, with tropical rains, as India, should glow when heated before O.P. in a platinum hook = (ii.); that is, *not* equal to pure lime, and should, in the same operation, fuse on edge. In E.P. it should afford a strong lime or (C) pyrochrome. In $\ddot{H}\ddot{B}$ it should easily form a clear ball, but part with a considerable quantity of opaline (alusiliceous) matter into the bead. The green pyrochrome should be unaltered, for free soda, though not potash, is evidently injurious to mortar. A little iron (2 or 3 per cent.) seems all the better.

(a) A fragment of good hydraulic mortar should also glow = (ii.), and fuse on edge in O.P., but in E.P. it should afford a less strong (C) or lime pyrochrome than the above (227). In $\ddot{H}\ddot{B}$ it also should give easily a clear lime, colored with iron, ball, but should afford to the bead, besides opaline matter, free silica in semitransparent masses. The green $\ddot{H}\ddot{B}$ pyrochrome should be unaltered, or even heightened (KO).

(b) The strange fact, however, is elicited from the above examples that the oldest mortar treated (226, g), that, namely, used 800 years since in the construction of the old ruined Palace, at Eltham, Kent, is of essentially the same

* Paragraph (140).

† Paragraph (216, g).

composition as the so-called Portland cement, which is not only a hydraulic mortar, but supposed to be a modern invention, and, moreover, apparently only differing from Kentish house mortar (226, *m*), in having "sharper" or coarser "sand," that is, pebbles the size of a pin's head mixed with it. *Concrete* seems nothing more than a combination of hydraulic mortar with roundish water-worn pebbles of all sizes down to that of a walnut, and this "sharp" sand, generally in the proportions: pebbles, 60; river sand, 25; lime, 15. An age of mortar making seems to have intervened, in which cow's hair and straw, &c., have been used as a binding medium, but that is a process a great deal too extravagant for the present economical time, and as a mortar in which "sharp" sand occupies so much comparative volume has lasted 800 years, it would evidently be folly to adopt for this climate any more costly material; the mortar giving reactions, as in (226, *p*), may therefore be allowed to pass as "open air" mortar, but great care must be taken in examining this, that, while free silica (semitransparent masses in $\ddot{H}\ddot{B}$) to some extent, is not to be objected to, there must be no free alumina (fat-like fragments) or soda (yellowish alteration of the green pyrochrome). It will have been observed that the mortar (226, *l*), 300 years old, the fracture of which could scarcely have been distinguished from that of a limestone rock, is the only case of those given in which the borate ball resisted the attack of soda, and there can be no doubt that it is by far the strongest of all, and would last, practically, for ever, provided the stones or bricks it held together lasted.

(*c*) The *soi-disant* "mortar" (case 226, *p*), taken by myself from between the bricks of the Agra Barrack, in 1871, was supplied by a native contractor to the Department of Public Works of the Indian Government, and is made, or said to be made, from the Kunkur with which the whole district abounds; an examination of which is given in (226, *l*); so that the reactions of the two may be compared. It will be observed that this "mortar" forms the only case in which soda is detected, and the reactions given, especially those in $\ddot{H}\ddot{B}$, show that this substance is little better than mud, with a small quantity (perhaps 8 or 9 per cent.) of lime and magnesia. The costly building from which this composition was taken is not yet one of the many Indian public buildings which have been ordered to be "abandoned" by the Government, lest they should fall on the heads of troops and others; some having actually fallen, and one at Allahabad, from the mortar of which just 5 per cent. of lime was obtained by a Calcutta chemist at the request of the late Lord Mayo, fell, and killed five or six people. But although this building has not yet been "abandoned" like the Sangor Barracks (which cost the public 166,000*l.*), it will have to be, sooner or later, unless bolstered up with constant repairs, which will soon double its cost. It is certainly dangerous; being roofed with large masses of sandstone, which must

require a particularly solidly cemented support, and as a company of one European regiment ran from under it during a monsoon storm, declaring they would not remain to be killed, it was not then inhabited for two years after it was built. The roundish pieces of raw kunkur in this "mortar" give the idea of imperfect calcination, but as there is a very considerable quantity of phosphoric acid in most kunkurs, I rather believe that, in this kunkur mortar, under the fierce tropical sun, calcic and magnesian phosphates are formed in concretionary nodules, which we know that acid has a tendency to form with many earthy bases; thus disintegrating the mortar, and leaving, in fact, little binding substance but clay or mud. It has been publicly stated in India without denial, that the Indian Government has lost 40,000,000*l.* by "abandoned" or ruined public buildings built of kunkur mortar in the last ten years, though, on the other hand, it appears to produce a fair hydraulic cement.

(*d*) At the Station of Mussoorie, in the Himalaya, the greater part of the neighbouring rocks is nearly pure calcic carbonate of a pale blue color, as may be seen from the fact that, towards the north, where the snow may be supposed to lie longest, the surface of these rocks has evidently been dissolved to a yellow sugary substance, flowing or dripping down, which, on being pyrologically examined, proves to be perfectly pure calcic carbonate. The mortar used by the inhabitants of this Station has the peculiarity of being composed entirely of this beautiful limestone, without any addition either of clay or any other substance. This may seem incredible, but it is a fact; and what is more, I have specimens from bridges and buildings which have stood at least for thirty years, and which would, I have no doubt, if required, stand as many centuries. It is, in fact, a kind of calcic concrete, in which the pebbles are represented by small pieces of raw blue limestone, evidently employed by the manufacturer as "sharp sand," in ignorance of its real nature. I have also specimens of natural concrete from the same place, in which the limy part, although as white as, and having the appearance of chalk, is so solid as to require heavy blows with a hammer to break it up; and it certainly seems strange that the different Indian Governments, having such wealth of magnificent limestone in this and other parts of India, should ever have thought of using kunkur in this way, except for hydraulic mortar purposes.

(*e*) Lime cannot be separated pyrologically, for detective purposes, from silica or from other bases more soluble than it is, by fusion with soda, as, e. g. baryta, because, although no combination takes place,* the lime is thereby rendered quite incapable of forming balls in *H₂*. The following process, there-

* I found, after this was written, that combination to a small extent *does* take place. *Vide* Paragraph (118, c).

fore, can be adopted, although it occupies some time, and may be considered to belong more to Quantitative Analysis. Let us take *Wollastonite* as an example. A calcined fragment is ground to a paste with a little $\text{H}\ddot{\text{B}}$ and water between agates, which paste is afterwards washed with a few drops of distilled water into a porcelain capsule, and the whole boiled until a solution having a starchy appearance and smell, and a yellowish-white residue, appears. A drop of this solution is placed on an agate for after examination in $\text{H}\ddot{\text{B}}$, and the remainder repeatedly washed with cold and then boiling water, from the residue. This latter is taken damp upon a platinum spatula (or foil), and heated before O.P. till it glows = (ii.). The curious fact will here be noted, that although the finely powdered fragment exhibited no remains of crystalline structure, the pieces left after this treatment are in the shape of long acicular crystals. These can be now taken up on an $\text{H}\ddot{\text{B}}$ bead, where under O.P. they at once form semi-transparent balls, with grammatic crystals on the surface (a small quantity of Si), and masses of free silica.* The drops of solution, dried gently and treated in a fresh $\text{H}\ddot{\text{B}}$ bead, afford a vitreous mass, gradually dissolving in O.P. to a clear glass which is very viscid, and becomes a fine blue-opaline color on cooling (silicic hydrate), not so beautiful as that formed by phosphoric acid in $\text{H}\ddot{\text{B}}$, but very characteristic, with a few transparent specks of undissolved silica, but not a trace of lime. Vesiculated, this bead gives a faint indication of potash; the green pyrochrome showed the absence of soda. There is thus produced a partial separation of the silica from the lime, leaving (in the residue) a calcic subsilicate, the proportions of which a quantitative pyrological analysis would easily show.

(f) Lime is easily detected when in conjunction with workable metallic oxides, as iron, copper, &c., in $\text{H}\ddot{\text{B}}$, by the rapid solution of these in the clear ball of the former, which is colored by their respective chromatic tints.† Fused with pure lead in a keyhole mortar on an aluminum plate, the resulting compound sublimate (in which plumbic oxide seems to act as the acid element) affords in $\text{H}\ddot{\text{B}}$ insoluble white fragments in an opaline glass, which is distinguished from that of tin treated similarly, by not becoming clear with the addition of fresh $\text{H}\ddot{\text{B}}$, while that does. Lime is also well thus distinguished from magnesia similarly treated, which does not form fragments, but an opaline glass.

(228). MAGNESIDES.

No substance is more easily recognized in $\text{H}\ddot{\text{B}}$ than magnesia, when in a free state, but when it forms a combination along with lime in a mineral, as, e. g. in *Dolomite*, the former earth seems absorbed in the reactions of the latter.‡ The most rapid way to detect MgO is by means of the E.P. A fragment of the mineral held in it shows, even if it also contains lime, a rose tint ($\text{H}\beta, d$), especially about the base of the pyrocone, having a little more red than the

* Compare this with (218, f).

† See the separate heads.

‡ Paragraph (226, b).

violet pyrochrome of potash, but not nearly so much as the smallest quantity of strontia bestows, while that is also observed nearer the apex of the pyrocone, and reddens the lime-orange. In $\ddot{H}\ddot{B}$ a fragment of magnesian carbonate under O.P. first glows = (iii.), and is then taken up with slight effervescence into the bead, where it forms a white, opaque, and perfectly round ball, like a miniature snowball, the effect of which, floating in the transparent bead, is very beautiful. After treating this bead for a considerable time with O.P., the ball suddenly glows with a phosphorescent light,* and is *then* found to have become transparent, while the heretofore perfectly clear and achromatic bead is, at the very same time, found suffused with a little opaline matter from the ball. This opaline matter has, on the ground of the reasoning already adduced,† been attributed to combined or chemical water, eventually exchanged by the caustic oxide for an equivalent of boric acid; and the tenacity with which, on such an hypothesis, magnesia retains this water, compared with lime, is quite in keeping with the refusal of the former oxide to dehydrate cobalt solution, even under O.P.

(a) But the most remarkable phenomenon connected with the behaviour of pure magnesia in $\ddot{H}\ddot{B}$ is the fact that, when the opaque white ball is at length clarified as above described, when it could not be distinguished from the ball formed by lime, if *fresh* fused boric acid be added to the bead under O.P. or H.P., the clear magnesian ball becomes *white and opaque again*, while that of lime remains clear. This change, according to the hypothesis here entertained, is due to the re-exchange by the anhydrous magnesian borate ball, of an equivalent of boric acid, for one of constitutional water, derived from the fresh $\ddot{H}\ddot{B}$, and this view seems confirmed by the two facts that the opaque ball is of less weight than the clear one; and that the $\ddot{H}\ddot{B}$ bead, which now contains an equivalent of anhydrous boric acid, is much less soluble in boiling water than it was before; hydration and solubility in water being in direct proportion.‡ The complete working out of this question can only be effected by means of the assay balance, and is therefore reserved for the volume on Quantitative Analysis, but meanwhile I submit that there are sufficient grounds here for believing the term "boric anhydride," applied in chemical works to fused boric acid, to be incorrect.

(b) One of the best pyrological methods of separating magnesia from lime is detailed in Paragraph (226, c); another is as follows:

Phosphorate an $\ddot{H}\ddot{B}$ glass by dipping it hot into a bottle of fluid $\ddot{H}\ddot{P}$, or by adding one or two small crystals of the fused $\ddot{H}\ddot{P}$ § to the former, under O.P., until the glass becomes nearly opaque on cooling. Then add the calcimagnesian compound (previously calcined) to the glass, and clarify the balls formed with O.P. Now cautiously add potassic carbonate, until the opalidity (or free phosphoric

* Paragraph (226, b).

‡ Paragraph (224, d).

† Paragraph (224, b).

§ Paragraph (114).

acid) is dissolved to a clear glass. Any calcic pyrophosphate in the ball rapidly dissolves to a clear but vitreous glass, leaving the magnesian pyrophosphate as an insoluble ball or balls not quite round. Chemically hydrated or platinized boric acid, that is, boric acid fused in a platinum crucible or capsule, and powdered, will also answer for this purpose, only the calcimagnesian fragment taken upon the hot dim bead should *not* be clarified by O.P., but the potash added to the bead containing the *opaque* ball or fragment. The calcic hydroborate apparently combines with the potash and uncombined boric acid, to form a clear vitreous bead; the magnesian hydroborate, on the contrary, remains as an insoluble opaque white mass even after so much potash has been added as gives a violet pyrochrome, and emits smoke.* Magnesia can also be readily separated and distinguished from lime by the treatment described above.†

(c) We have seen‡ the behaviour of calcic silicates in $\ddot{H}\ddot{B}$, and that should be compared with the following description of a magnesian silicate (*Talc*). In O.P. a fragment (which should not be heated sufficiently to fuse on edge) glows = (ii.), or more brightly than a magnesian calcic silicate.§ In E.P. gives a strong (D) pyrochrome with a slight rose tint. In $\ddot{H}\ddot{B}$, instead of forming a large ball as a calcic silicate does, the fragment is decomposed, many very small and clear (because they are so small, and cannot remain opaque under this amount of heat) balls issuing from the fragment, which is left as a "skeleton" or silicious semitransparent mass. It is difficult or almost impossible to aggregate these small balls into one large one, although they are seen through the lens by the transmitted light to be perfectly clear, free from (Si) crystals, and may therefore be presumed to consist of pure magnesian borate. They are proved to be different from calcic borate balls by heating the bead in O.P. until it is considerably reduced in size, and then fusing on some fresh $\ddot{H}\ddot{B}$, when most, if not all of them, become opaque and white.|| The opaline matter given off has a slight porcelain appearance.

(d) *Meerschaum* (*Sepiolite*) behaves like *Talc* under the above-mentioned treatment, except that a fragment is indecomposable in $\ddot{H}\ddot{B}$, and must, therefore, be reduced to powder between agates, the resulting small clear balls being easily distinguished from those of calcic borate by the difficulty of aggregation under O.P., for a large addition even of fresh fused $\ddot{H}\ddot{B}$ does not render such small magnesian borate balls opaque. More opaline matter, also, is rendered to $\ddot{H}\ddot{B}$ under O.P. by *Sepiolite* than by *Talc*, and in both cases it is proved to be due to chemical water and not to phosphoric acid by the addition of a minute speck of potassic carbonate, when a clear, not a blue, bead results.¶

* Paragraph (221, d).

§ Paragraph (226, f).

† Paragraphs (227, f) and (226, c).

|| Paragraph (226, b).

‡ Paragraph (226, j).

¶ Paragraph (216, c).

(e) *Impure or imitation Meerschaum*, from a pipe which possessed all the outward characteristics, lightness, color, sticking to the tongue, &c., of real Meerschaum.—A fragment in $\text{H}\ddot{\text{B}}$ unchanged, but one or two very small clear balls eliminated: on being first heated it smelt strongly of burning wax. (2) The fine powder gave thick opaline streaks with a few silicious (transparent) crystals disseminated; this, after O.P., spread over the bead as grey opaline matter, proved to be due to water by K_2CO_3 ;* no balls. (3) A fragment in O.P. glowed = (iii.); after this, lost its yellowish creamy or soapy appearance, and became white and like pipe-clay. (4) The powder of (3) gave in $\text{H}\ddot{\text{B}}$ masses, partly fat-like and partly transparent, with a quantity of opaline matter and a few clear balls. The stuff, therefore, consists of aluminic silicate (clay) with some hydrated magnesian silicate; the whole (probably) ground up into a paste with melted wax or boiled in that. The remarkable fact in the above is, that the wax seemed to have the effect of rendering the silica and alumina soluble in $\text{H}\ddot{\text{B}}$.

(f) Magnesian silicates made to a paste between agates with a little $\text{H}\ddot{\text{B}}$, and a drop of water, and then boiled in water acidulated with $\text{H}\ddot{\text{B}}$, are wholly dissolved, and can thus be readily separated from lime, but on cooling, a flocculent or gelatinous precipitate appears, which, however, being treated in $\text{H}\ddot{\text{B}}$, gives no balls, but only grey opaline matter, which can be distinguished from that afforded by silica identically treated, by the fact that the former is opaque even while red hot, while the latter is clear. Made into a paste with K_2CO_3 , and boiled for several times with fresh water, a flocculent precipitate is given, which appears to be magnesian hydrate, and only to afford opaline matter in $\text{H}\ddot{\text{B}}$.

(229). DIDYMIDES and LANTHANIDES.

Cerite: appearance, purplish, stony. In O.P. glows = (iii.), and shows on the surface of a fragment (a) a greenish oxide; (b) a black substance which fuses; (c) a red oxide; (d) white semitransparent facets like silica, which are found next the point of the pyrocone. In a weak O.P. the whole surface is covered with (a) and a little (c) only, the remainder of the fragment becoming a delicate purple. Amongst the powder of one specimen I examined were several but not numerous flat scales with metallic lustre and a slightly iridescent or bluish color. These were so minute that I had to collect them from the mineral, powdered between agates with water, by the aid of a powerful lens and the point of a fine needle. In $\text{H}\ddot{\text{B}}$ they were utterly unaltered under the strongest O.P., and might, therefore, be Iridium, or one of that series of metals.

(a) The behaviour of *Cerite* in $\text{H}\ddot{\text{B}}$ has been already described under Cerium,† but if a largish fragment (the size of a pin's head) of the calcined mineral be applied to $\text{H}\ddot{\text{B}}$ it slowly fuses into a ball having the color and

* Paragraph (216, a).

† Paragraph (219).

appearance of brown sugar, emitting the while a bluish flocculent opaline matter which is evidently phosphoric acid, and is proved to be by treatment as described in (213, c).

(b) Crushed with water and $\text{H}\ddot{\text{B}}$ between agates, and the paste boiled with water acidulated with $\text{H}\ddot{\text{B}}$, silica and ceria are separated in solution, and the residue, a greenish-white powder, affords in $\text{H}\ddot{\text{B}}$ a greenish-yellow opaque ball with white crystals (CeO ?) round it, which it requires long and strong O.P. to clarify; after which the ball is opaque while red hot, but transparent at a lower temperature. This ball clings to the platinum ring under O.P., but is easily detached again by H.P. Some grammatic crystals on the surface show it still to contain a little silica or ceria, or both. It should then be purified by repeated treatment in fresh $\text{H}\ddot{\text{B}}$ beads, after two or three of which the ball assumes the pretty violetish-red or "strawberry" color of didymic oxide, and on extracting the ball finally from the bead by boiling, bluish fragments, also transparent, seem to separate from the former, which form in $\text{H}\ddot{\text{B}}$ violet-blue balls, and these latter were also separated from the violetish-red ball near the end of the refining process in fresh $\text{H}\ddot{\text{B}}$ beads, by simple O.P.; I therefore conclude them to be balls of anhydrous borate of lanthanum, which when pure will not apparently combine with the didymic balls in $\text{H}\ddot{\text{B}}$.

(c) A fragment of *Cerite* the size of a pin's head was treated as follows. The reactions are not all understood, simply because it is impossible to get any of these oxides pure from the chemists, as they have never been separated; at any rate, those at the Royal Institution, the British Museum, those sent from Görlitz, in Prussia, &c., were all found to be combined together, and yet we find the atomic weights of each carefully laid down in the chemical works! (1) Applied without calcination to an $\text{H}\ddot{\text{B}}$ bead under O.P. phosphoric acid was emitted as described in (a) with a yellow-brown ball. (2) A few specks of K_2CO_3 dissolved the $\text{H}\ddot{\text{B}}$ to a blue opaline glass, clear hot, without injuring the ball (different from lime), and the bead was treated in O.P. until no more opaline matter was emitted. (3) The ball was then extracted by boiling, crushed between agates with a little $\text{H}\ddot{\text{B}}$, and the paste boiled in $\text{H}\ddot{\text{B}}$ acidulated water. This afforded a flocculent matter in solution (which gave the reactions of soluble silica in $\text{H}\ddot{\text{B}}$), and a yellowish-grey residue. (4) The latter afforded three distinct reactions in $\text{H}\ddot{\text{B}}$, (α) a finely diffused precipitate which rendered the whole bead nearly opaque, white, but not opaline, nor even clear hot, (β) a greenish-yellow large ball, (γ) several very small balls nearly transparent but bluish. The whole essay is very unsatisfactory, being blind work, but it will at any rate serve to recognize the mineral *Cerite*.

(d) Chemically prepared, Didymia from Görlitz is a pinkish-white powder, which a hot glass being applied to it turns pinkish-brown, and remains so

unless treated with P.P., when it becomes yellow. It forms a strawberry-colored clear ball in $\text{H}\ddot{\text{B}}$, which, if saturated, evolves beautiful white prismatic crystals pointed at each end like leaves of the Cape aloe, while part forms an amorphous opaque barleysugar-like mass. The tendency to crystallize thus in $\text{H}\ddot{\text{B}}$ renders the production of a large, transparent, strawberry-colored ball of didymia a matter of considerable difficulty. The ball must be *caught* upon the platinum ring in an $\text{H}\ddot{\text{B}}$ bead not too large, and there subjected to a *very* strong O.P., the fine point of the blue pyrocone being kept upon it until it seems, while white hot, to be also clear. A little practice soon shows this to the operator. The pyrocone is best applied with a table pyrogene. The clear strawberry-colored ball affords a very interesting spectrum. The thick black lines to the right (or green side) of (D), and those on either side of (Eb), are so powerful as to cause the spectrum to appear like a ladder with very thick black steps, and when the solution is very strong and the ball very clear, an intense, but not thick black line appears near that of lithia in the solar spectrum. In the ratio of strength of solution, the lines near (D) appear first, then that to the right of (E), then that to the right of (Eb); the comparatively thin solar line (Eb) passing just between these two thick didymic lines (Table VI.); lastly, the line in the red, near that of lithia, appears; a reaction certainly calculated to afford quantitative results. For Didymia, it must be allowed that no other mode of detection comes near the delicacy of this. *O! si sic omnes*. For the spectrum of a weak solution of didymia, see Paragraph (255, a).

(230). MANGANIDES.

The curious fact, only discovered by me a short time since, that manganic dioxide affords black vitreous balls in $\text{H}\ddot{\text{B}}$, which after a short treatment with O.P. become transparent and colored ($\text{D}\eta + \text{H}\beta$, or 2·1, or nut brown), compelled me to change the place of this metal in my table* from near Iron to the position next Didymium and Lanthanum, which, with it, are the only three oxides which afford (so far as I know) colored transparent balls in $\text{H}\ddot{\text{B}}$.

(a) The pattern oxide I use,† which seemed perfectly pure by every other test, was proved by $\text{H}\ddot{\text{B}}$ to contain a by no means inconsiderable amount (about ·05) of hydric phosphate, and this is unfortunate, as its reaction obscures that of zinc oxide, for instance, added to the glass to ascertain the appearance in $\text{H}\ddot{\text{B}}$ of such minerals as *Franklinite*. In this mineral, however, manganic and ferric oxides are seldom so plainly and separately distinguished, that no further test is required for them (the ferrimanganic balls being black and

* Page 178.

† Another specimen of "pure" oxide from a laboratory, contained only 80 per cent. of manganese!

opaque like those of iron alone), but the copious opaline matter evolved is more than sufficient to lead the operator to determine it.*

Manganic and ferric oxides are both of them qualitatively isolated and detected in such minerals as *Franklinite* and even *Almandine* by treatment as in Paragraph (139 (2) a, b). On a platinum hook in E.P. a fragment of *Franklinite* gave a distinct lime reaction. The most rapid way of obtaining an indication of manganese is by heating a largish fragment of the mineral on aluminum plate in O.P. at *one end only*, when MnO_2 will generally be found as a coffee brown efflorescence at the other, or cool end. Iron, on the contrary, generally appears as a blood red sesquioxide *at the heated end*. Manganese seems to have a yellow-green pyrochrome in O.P.

(b) The manganoborate balls possess the same property as the borax bead colored with this oxide of becoming colorless in H.P.; the only difference is, that the latter requires a quantity (about 5 mgrs.) which would completely "swamp" an $\ddot{H}\ddot{B}$ glass, which will determine a speck, scarcely visible without a lens, of the powdered oxide to be MnO_2 . It forms thus as delicate a reagent for this oxide as soda, which, according to Plattner,† turns bluish-green when fused with .1 per cent. of MnO , while the indescribable advantage is possessed by the former, that, so far from being a special reagent for this one oxide, it shows at the same moment the presence of almost everything else which may be in the mineral, and is used *in the ordinary course* of analysis. Chromic sesquioxide, which somewhat mars the effect of the soda test for Mn, by altering the color, is at once separated from the latter in $\ddot{H}\ddot{B}$, in which the former does not form balls.

(c) Manganic dioxide "effervesces" so violently on first fusion in $\ddot{H}\ddot{B}$ as to lead the operator to suspect the presence of sulphuric or carbonic acid, were the essay any other oxide, but with this one, the escape of gas must evidently be due either to the decomposition of the MnO_2 or to that of the $\ddot{H}\ddot{B}$. The fact of the balls having the same color (brown) as the oxide added, does not lead to the former inference, while if the latter phenomenon takes place, there is no outward sign of it in the appearance of the bead, which seems, however, a little less soluble in boiling water.

Rhodonite and *Diallogite* ‡ both afford in E.P., the latter a strong, the former a distinct lime pyrochrome (Plate II., C). *Diallogite* shows also magnesia ($H\beta$, d). In $\ddot{H}\ddot{B}$ *Diallogite* affords a pure Mn reaction. With chemical water *Rhodonite* forms at first a roundish fragment with a dark nucleus, giving off a considerable quantity of opaline matter, which leaves the edge of the mass semitransparent (soluble and insoluble silica), but a ringed bead § under a high-angle O.P. || soon decomposes this, the mass emitting clear balls, which are

* *Fide* Zincides.

† Page 271.

‡ The decrepitation of *Diallogite*, if used as a fragment, must be first neutralized, as explained in Paragraph (160).

§ Paragraph (140).

|| Paragraphs (83), (86).

brown after O.P., colorless after H.P. cold (MnO); some balls having grammatic crystals (silicate, second class), and being yellow hot after H.P. (iron).

(d) When manganese occurs with cobalt oxide and silica, the soda test is useless, as a blue mass only from the latter is obtained, and in this case Plattner recommends a recourse to the "wet way," but the use of $\ddot{\text{H}}\ddot{\text{B}}$ and a fragment of lime obviates this necessity, as cobaltine-calciborate balls are much more easily distinguished from manganic ones than those of Iron,* for these form clear balls, colored ($\text{G}\delta$, a), which cannot be mistaken.

(e) In a bead of phosphoric acid, powdered, taken up on the white hot glass MnO_2 gives bubbles, tinged blood red when cold, and after, in P.P., is betrayed by a pink tinge on cooling, in much less quantity than is required to color either Mic. salt or borax (about .1 mgr.); but the second reaction is of course not so delicate as that given by $\ddot{\text{H}}\ddot{\text{B}}$; .5 per cent. of the binoxide gives a fine violetish-red glass, and 1 per cent. a magnificent carmine ($\text{H}\gamma$). In P.P. many bubbles appear to spring out of the bead, which stop in H.P., and thus afford good practice for the learner.

(f) It is a curious fact that, although pure manganic oxides communicate to a peroxidized $\ddot{\text{H}}\ddot{\text{P}}$ glass the beautiful carmine tint referred to in (e), their combination with ferric oxide (which also affords a reddish $\ddot{\text{H}}\ddot{\text{P}}$ glass),† should give a yellow tint to the glass not unlike the peroxidized ferric borax bead.‡ Of the peroxidized ferric and ferro-manganic $\ddot{\text{H}}\ddot{\text{P}}$ glasses, therefore, the former is the most highly colored, and although the fact is sufficient to enable the experienced operator to confidently declare the presence or absence of much iron in a manganic, or much manganese in a ferric mineral, still we have been so accustomed to associate an "amethystine bead" with the presence of manganese, that some confusion might occur. This is avoided by using as a reagent a barytoboric glass, made by adding to a boric acid one carbonate of barium, until the clear ball formed pervades the whole glass.§ This forms by far the most delicate detective of manganese in combination even with the most chromatic oxides, as in *Asbolane*,|| between the glass of which and that colored by pure cobalt is a difference so wide, that the second tint is a prismatic ($\text{G}\beta$), the first a complementary ($2\cdot9$) combination. *Franklinite* applied to a barytoboric glass produces a fine orange tint, almost equal to that of a small trace of nickel oxide in $\ddot{\text{H}}\ddot{\text{P}}$, while the glass colored with iron alone is a dark olive. Tantallic and columbic acids seem to have the curious property of decolorizing the barytoboric glass colored with iron and manganese, as in *Columbite*, the glass of which mineral is almost colorless, while the calciboric glass is a brilliant brown.¶

* *Vide* Paragraph (259, d).

§ Paragraph (232, d).

† Paragraph (259, c).

|| Paragraph (143, a), XI.

‡ Plattner, p. 127, table.

¶ Paragraph (528).

(g) Manganic oxides can be readily separated from iron, *et id genus*, by fusion of the essay with lead in a keyhole mortar on aluminum. The highest or white part of the scraped off manganate of lead affords in $\ddot{H}\ddot{B}$ a semiopaline glass with white fragments like those of tin, but continued O.P. resolves these into clear balls, which P.P. renders brown and transparent; H.P. colorless again. This is perhaps the best way of detecting manganese in complex minerals, for although zinc also thus treated affords balls in $\ddot{H}\ddot{B}$, those are colorless under any pyrocone.*

(h) The manganic reaction with soda in P.P. on aluminum plate is greenish-blue of a light shade (F β , c), the freshly-made cold bead being very similar to a pale *Turquoise*, and appears to show much the same tint on platinum foil, though Plattner calls that "distinctly bluish-green."† The spheroidal form of the essay on aluminum plate enables the color to be better observed. This beautiful color entirely disappears after the application of an H.P., manganese binoxide apparently being formed, as black-brown spots are then seen, the rest of the bead being (if no other oxide is present) a perfect opaque white. Iron oxide, which cannot be collected into spots by H.P., is thus well distinguished from that of manganese.‡

(231). CADMIDES. I was compelled to place Cadmium in the position it occupies in my table, by the curious fact that the pure oxide, although of an orange-brown color, affords in $\ddot{H}\ddot{B}$ under O.P. balls as transparent and colorless as those given by lime. It also thus emits a woolly opalescence, as zinc oxide does, from which metal (in combination with which it is chiefly found) it is distinguished by the ball formation above mentioned, as also by the fact that the cadmic opalescence becomes reddish in H.P.

(a) In $\ddot{H}\ddot{B}$ cadmic oxide dissolves rapidly with effervescence to a transparent and colorless, but extremely vitreous glass, and when added to a certain point (not yet ascertained) of saturation, roundish or botryoidal, white, opaque crystals or concretions form about the centre of the glass, when that is held in a candle H.P. They will not form after a gas H.P., from which fact it may be fairly concluded that carbon has something to do with their formation.

(232). BARIDES.

Baric oxide and carbonate behave in a very peculiar manner in $\ddot{H}\ddot{B}$ under O.P. At first they form a transparent and vitreous ball, like that of lime, but under continued O.P. a very large quantity of thick, curdy, opaline matter is emitted, which clings round the ball, making it appear white and opaque, though it is not really so, as it is transparent when extracted by boiling. In H.P. the ball loses its spherical shape, becoming oval, and breaking up into smaller ellipsoids like miniature eggs, while the curdy opalescence connects these together;

* Paragraph (262, c).

† Page 271.

‡ Vide Ferrides.

in fact, the whole shows a tendency to form a stringy opalescent mass, like that of metals in the next class which afford sublimes. Baryta does not do that, but it is extremely poisonous, like arsenic, while the alkaline earths are not merely wholesome, but one of them (lime) seems absolutely necessary to both animals and plants as food for the support of life. Besides, Barum gives in O.P. and E.P. a green pyrochrome, like that of molybdenum, and is placed next to that in the table, because it seems to form the link between the ball-forming and the stringy matter emitting oxides in $\ddot{H}\ddot{B}$, the green pyrochrome of which it renders more vivid.

(a) *Barite* forms a remarkable exception to the facility with which other salts of barium form balls in $\ddot{H}\ddot{B}$, in which the sulphate is utterly undecomposed, even in a ringed bead under high-angle O.P.* In this behaviour, with the exception of silicates and aluminates, the only other salt resembling it is magnesian phosphate, and both of these withstand the taking up of a large proportion of potash before dissolving in the bead. Something in the same manner as in the "wet way," therefore, baryta may be separated from lime by means of sulphuric acid, which can be added to an $\ddot{H}\ddot{B}$ bead or glass by means of magnesian sulphate, and the resulting insoluble baric sulphate separated in the usual way. *Barite* is said (by Plattner) to give a "yellowish-green" pyrochrome in O.P.; to me it appears more like green-yellow. In E.P. it affords an orange pyrochrome with (at first) a bright green tinge; which facts, taken in connection with the strong HS smell of its steam, and its remarkable behaviour in $\ddot{H}\ddot{B}$, indicate *Barite* to an operator of ordinary acuteness. Pure sulphur is easily separated from *Barite* as follows: Treat a ball of the paste made with water between agates in a good candle H.P. (a gas one will not do) made with a (β) platinum jet† for two minutes: the ball becomes black towards the front or base of the pyrocone, but this blackness vanishes when the essay is removed. On adding water to the hot mass on platinum foil, the blackness returns, and the steam smells strongly of HS. If the moist mass be now heated in a long P.P., the sulphur appears on the surface as a lemon yellow incrustation; but continued P.P. apparently reconverts what is not evaporated as SO_2 into sulphuric acid, which combines with part of the base, for the mass becomes white again. The *rationale* seems, that sulphide of carbon is formed by the double decomposition of the salt and the hydrocarbonous pyrocone; that the water added to the hot sulphide causes another double decomposition; hydric sulphide and carbonic oxide rising, while sulphur is left, if too much heat be not applied. A similar result may be produced much more rapidly on the edge of a fragment of *Barite* in which decrepitation has been cancelled by boiling,‡ by treating it in E.P., the heat of which is very low, and the

* *Vide* Paragraphs (86) and (140).

† Paragraph (81).

‡ Paragraph (160).

water being supplied from the oil in the wick by touching that with the fragment.

(b) Salts of Barium, which form balls in $\text{H}\ddot{\text{B}}$, immediately *heighten* the green pyrochrome of that reagent so considerably as to be at once perceived by the careful operator, though the green thus produced is by no means so brilliant as that given by the addition of copper. Unless these two substances are together, therefore, in the essay, this fact forms one of the best detectives of barium in combination.

(c) Baryta fused with sodic carbonate on aluminum plate in O.P. forms (apparently) a pyrochemical combination as a fluid bead clear hot, opaque white cold, over the surface of which spread on cooling comparatively large crystalline planes, evidently of a perfectly different character from those produced by fusing soda *per se*.

(d) Baric Hydrate or Carbonate (pure *Witherite* powdered answers very well), when added in excess to $\text{H}\ddot{\text{B}}$, soon dissolves the opaline matter emitted into the bead by the first ball,* and when that is effected, and a transparent achromatic glass formed, an excellent flux for testing several of the chromatic oxides in combination with each other has been produced.† It is especially excellent in the detection of manganic in presence of cobalt oxide, as in *Asbolane*, or of ferric oxide, as in *Franklinite*, in the first of which cases the color (G β), which it produces with cobalt oxide alone, is modified to (2·9), and in the second case, the iron color, olive, is changed to a red-brown or orange.

(e) The Barytoborate glass is also (as might be expected) a good reagent for detecting sulphates, which are insoluble in it, while their basic oxides are rapidly dissolved; as, for instance, *Gypsum* and lime.

(233). OXYGEN.

We find, on coming to this point of our Table of Metals, a remarkable change in the behaviour of oxides formed upon them by the application of pyrogenical heat. Up to this point, the metalloids (with the exception of Boron and Silicon) and metals, ignite under such conditions; burn with brilliancy, and are instantaneously converted into oxides. The metallic oxides thus formed, however, are very stable under further heat, and either fuse, burning slowly away, or glow intensely, and do not burn at all. Then, as regards the class of metals which immediately follows this point, the application of O.P. to most of them, causes those to fuse so rapidly on charcoal that they may be almost said to boil, and, during this ebullition, to oxidize so quickly and completely that the oxide rises as a kind of smoke, in greater or less volume, and this is called their "sublimate." Supposing pure hydrogen to represent an hypothetical line in the pure red of our circular spectrum at (A), and pure water one in the

* Paragraph (232).

† Paragraph (111).

orange at (D), elementary oxygen would occupy a line about this point (De) of the spectrum, or pure yellow. (Plate II.)

(a) It is to be observed, also, that the pyrochrome of those preceding metals which afford one, with the exception of that of boron and phosphorus (the oxides even of which, by the way, both afford a sublimate), always contains red, whether it approach the yellow side as in sodium, or the violet as in potassium; also that the pyrochrome of lithia, the deepest toned red of any ordinary metal, is emitted from that one whose atomic weight approaches nearest to that of hydrogen. The (H) or violet pyrochrome of potash may be obtained from melted wax by playing the H.P. of a pyrological candle back over it.

(234). VOLATILE AND VOLATILIZABLE METALS.

The curious fact with regard to these is ascertained by heating them on aluminum plate,* that, apparently, contrary to chemical axioms, the highest or acid oxide of the metal is the most volatile, whereas it ought of course, by those laws, to be the heaviest and least volatile. This is apparently determined beyond a doubt by the phenomenon described before.† Plattner, who found this superior volatility of the first eliminated oxide of antimony in a glass tube,‡ gets over the difficulty in an orthodox manner, by making it the more basic oxide of the two; whereas, if he had tried it with moist test paper, he would have found that it is the highest, or acid oxide. The leopard spots caused by this oxide on steel, seem due to the combination of the antimonie anhydride with atmospheric water, on its way up the aluminum plate, which the antimonie acid thus formed is unable to attack, but the steel being more vulnerable, it deposits there, leaving its mark. It is almost amusing to see how, in order to suit modern chemical theories, even conscientious writers twist the most simple natural facts into strained artificial explanations. Plattner, for instance, tells us§ that on heating pure lead on charcoal, "the yellow coat is pure oxide of lead, and the bluish-white one, carbonate;" the *carbonation* being supposed to be due to the chemical effect of the ignited charcoal on the plumbic oxide, but the *rationale* of the conversion is unexplained. The fact seems to be that there is a white *oxide* of lead, formed by volatilization, and deposited above or beyond the yellow oxide from its minor specific gravity. At any rate, it would puzzle even chemical ingenuity to formulate a theory for the production of plumbic *carbonate* by heating the purest lead in O.P. upon burnished aluminum plate, and yet "white lead" is undeniably, though not copiously, thus produced; the white sublimate, indeed, being distinguishable from that of antimony by not blackening or changing in O.P.; without charcoal, lead produces no yellow sublimate in O.P., except sometimes just *under* the essay. If *this* "white lead" then is a carbonate, the carbon must have been derived from the metal itself.

* Paragraph (129, d).

† Paragraph (129, f).

‡ Page 428.

§ Page 82.

In his qualitative analysis of *Galena*, Plattner further states,* that the white sublimate is "sulphate of lead," but without any explanation of the cause.

(a) The yellow sublimate afforded by sulphides of arsenic and antimony on aluminum plate can easily be distinguished from that of lead or bismuth by the volatility of the former in O.P.; and it struck me to turn this peculiarity of the two former metals of affording a golden brown sublimate in combination with sulphur to account, by thus using antimonial oxide to distinguish between sulphates and phosphates. These are separately ground to paste between agates with a little antimonous oxide, and, on treatment first with H.P., and then with O.P., the sulphate at once affords, just above the black halo of antimonial suboxide round the essay, large gold brown metallic-looking spots of, I suppose, antimonious sulphide. The phosphate yields nothing of the sort.

(b) In treating volatilizable metals on aluminum plate it will be observed how the mere process of placing a small slip or "mortar" of charcoal between the essay and the plate not only decomposes the former, but, with anything like a strong O.P., separates numerous metallic globules from it, which are not separated anything like so copiously when it rests directly on the plate, so that this loss would thus be avoided. Some idea may be formed of the probability and gravity of such a loss in the process of cupellation, from a knowledge of the fact (distinctly shown by roasting on charcoal supported by aluminum) that the pink sublimate of silver is separated simultaneously with the white sublimate of lead,† both being covered with innumerable minute globules of *metal*.

(c) Chlorides, as, e. g. common salt, afford a copious white sublimate, which is certainly not, as stated by Plattner, the chloride volatilized intact, because an evident decomposition has taken place; the sublimate gives to moistened litmus an acid reaction; the soda left is sharp to taste, and caustic. This should be tried on platinum wire, as chlorine with soda seems to attack aluminum. Besides, the sublimate given by such a volatile substance as ammoniac chloride, which may be safely volatilized on aluminum, is not nearly so volatile as the essay from which it is derived, withstanding O.P. on the steel forceps for some time, and at last vanishing with the unmistakable smell of *Chlorine*.

(d) Plattner states,‡ that potassic, sodic, and lithic sulphates, having been first converted to sulphides on the charcoal (strange, that plumbic sulphide should, according to him, by similar treatment, be converted to sulphate!), "volatilize, and are oxidized, giving a white coat of neutral sulphates:" but no such confusion can occur on the aluminum support, and if it did, such sulphates are not likely to interfere with this examination of the volatilizable metals.

(e) It will have been observed from a perusal of the foregoing, and of

* Page 343.

† Paragraph (243).

‡ Page 84.

Paragraph (126, *f*), that the *rationale* of treating volatile and volatilizable metals on aluminum plate is (what cannot be effected on charcoal alone) essentially one of *successive separation* by exhaustive volatilization. (1) The essay, containing an (α) number of these metals, being first treated *per se* on the plate, evolves as a sublimate only that metal (with the exception of mercury, arsenic, and zinc, which invariably rise) which stands highest in the scale of volatilizability, in the mineral or compound. For instance, under a mild O.P., in a compound of antimony (α) and lead (β), the sublimate (α) would first rise; (β) would not. In a compound of lead (γ) and silver (δ); the sublimate (γ) would first rise; (δ) would not. From the nearly rectangular (that is, having a nearly perpendicular long side) nature of the aluminum support, there is no danger (as there undoubtedly is on horizontal charcoal) of one sublimate, whatever its comparative specific gravity, being blown over another by the superposed blast.* (2) When a charcoal mortar is slipped under the essay, these conditions are evidently changed. A rapid and universal decomposition of the essay, even under a mild O.P., at once takes place; sublimates are eliminated *pêle-mêle*; one spreads over the other, and this again over that, *in the line of fire*, though in afterwards ascending the nearly perpendicular aluminum plate, superposition does not, apparently, take place, and sublimates are arranged in order of ascension in the inverse proportion of their specific gravities. Thus, in order to detect mercury, arsenic, zinc, *and* the lightest of the volatilized oxides, operation (1) is performed; to detect the remaining volatilizable metals, and the final base in the essay, operation (2). Sulphur in combination certainly renders, at first, all these metals more volatile in operation (1), but soon forms a fusible, comparatively stable compound of all, which seems to be regulated in volatilization by the above-described "law."

METALS WHICH AFFORD A SUBLIMATE IN O.P.

(235). MOLYBDIDES, Molybdates.

Molybdenum is readily recognized in any combination by the very beautiful deep-toned (or "indigo") blue sublimate (which I call a "peacock halo") it affords to H.P. on aluminum plate, both *per se*, and when the yellowish-white sublimate also formed is touched by that, which is given by no other substance; as also by the curious fact that a proportion under 5 per cent. of an $\ddot{\text{H}}\ddot{\text{B}}$ glass, colors that greenish-blue ($\text{F}\beta$) on cooling, while a larger quantity colors it blue-green or (F). In $\ddot{\text{H}}\ddot{\text{B}}$ insoluble, as black fragments, which potash or soda dissolves without giving chromatic effects. The native sulphide gives a ($\text{D}\eta$) pyrochrome. The so-called "pure" molybdic acid of the shops generally contains a considerable quantity of oxide of lead, as may soon be seen by

* Paragraph (84).

comparing the reactions in $\ddot{H}\ddot{B}$ of some of the crystallized acid obtained by oxidating *Molybdenite* on aluminum plate, without charcoal, with those of the purchased "pure" acid, which gives, in addition to the former, the marked indications of plumbic oxide. The crystallized acid is nearly insoluble in cold water; the sublimate very soluble. The purchased acid behaves, in fact, very much like *Wulfenite*. Molybdic, like tungstic acid, is an excellent detective for phosphoric acid, and is in its turn detected by that, as in *Uraninite*; but as it is much less soluble in an $\ddot{H}\ddot{B}$ glass with addition of potassic carbonate, and then leaves it slightly colored, it is decidedly inferior to tungstic acid as a reagent for phosphoric acid.

(a) *Wulfenite* does not afford much of a peacock halo on aluminum plate; that of the lead present obscuring it; the white border also turns only greenish when touched with H.P. Molybdic acid, however, is at once detected by treating an $\ddot{H}\ddot{B}$ glass under O.P. with this halo, the whole of which only colors the former = (F β), as above explained (236); while a small trace even of the crushed residue (which has a beautiful purple color) renders a similar glass = (F).

It seems evident from this fact that molybdate of lead is not volatilized, or that a large proportion of sublimed plumbic oxide mechanically accompanies molybdate of lead upwards: which latter hypothesis seems less likely.

(b) It is quite impossible to understand the necessity for the long tedious process given by Plattner;* the fusion with nitre and soda; treatment with hydrochloric acid and copper, &c., for the simple detection of molybdic acid in *Molybdenite*. If a fragment of that mineral on a charcoal mortar over aluminum plate, or on the bare plate, be treated on its edges with P.P. till the (D η) pyrochrome impinges on the plate, a copious yellowish-white sublimate will be found there, and molybdic acid in large crystals on the under side of the fragment itself; if now this sublimate be touched with a momentary H.P. (a continued H.P. turns it black), an indigo blue, deeper in tone, but quite equal to ultramarine in tint, will be found on the touched spots. With a drop of water and a small paint-brush this affords on a sheet of paper a neutral tint † of good "body."

(c) The green pyrochrome of *Uraninite* in O.P. is 'perhaps due to the presence of molybdic acid; certainly not of copper, as stated in Plattner's 'Pröbirkunst,' and most works on mineralogy.‡ The outer border of *Molybdenite* sublimate on aluminum plate affords in $\ddot{H}\ddot{B}$, though applied in any quantity, a beautiful pure blue glass; this, therefore, seems a *higher oxide* than the rest of the sublimate which affords a blue-green or (F) glass. The reason of a *small*

* Pages 436, 437.

† 3-5, Pl. III.

‡ Vide Paragraph (258).

proportion of the mineral, therefore, affording a greenish-blue $\text{H}\beta$ glass, seems that that amount can be more highly oxidized by this flux than a larger quantity. In $\text{H}\beta$ this sublimate affords black insoluble fragments.

(236). ARSENIDES, Arsenates.

The question here is to obtain rapid and delicate, but reliable, indications of this poisonous metal, even in presence of antimony, without the use of complicated, fragile, and unportable apparatus, such as Marsh's or Reinsch's, or modifications of those. For this purpose the gas is turned low, or the pyrological candle heaped with wax till a flame of one inch is procured. The essay is placed on the nearly rectangular ledge of a piece of aluminum plate,* which has been previously burnished with ivory; held by the (θ) pliers, and treated with a gentle, increasing to a strong O.P., when, perhaps, no sublimate is evolved by the first, but the acid exhalation, causing leopard spots on the steel, is sure to be observed. If the essay fuses to a ball, but shows no sublimate opposite it on the shining aluminum, it must, nevertheless, not be concluded that no arsenic is present, for this metal seems, like sulphur, to form, with a base, fusible fixed compounds, containing different proportions of the "negative" element. The ball is therefore placed in the same position as before, but upon a slab or "mortar" of charcoal, three or four times the diameter of the ball, and again treated with a similar O.P. A minute trace of arsenic combined (even with cobalt) will now be given up, if the essay be very small, and can be retained on the charcoal without being blown away; if not, it must be fixed with a small (pin's head) piece of $\text{H}\beta$ affording the following characteristic phenomena: (α) The garlic smell, which is overpowered by that of a large piece of charcoal, and not perceived. (β) A beautiful iridescent halo or rainbow *over* the essay, on the shining aluminum plate, with (γ) a patch of white sublimate in the centre. This latter is tried with O.P. to see (by its turning black) whether it be not antimony: if it vanishes rapidly, it is arsenious acid, and not antimony. If there be more than 5 per cent. of arsenic in the essay, a white sublimate, and no iridescent halo, will be formed. In the above way arsenic is readily detected in a crystal of *Jeypoorite*, weighing only .7 mgr., although it forms only at the most 10 per cent. of that or .01 mgr. of arsenic is detected.† Strongly heated in a glass tube, nothing but an acid faint white sublimate, which might be anything, is evolved. A large proportion of arsenic gives on aluminum plate, (α) a white *crystalline* efflorescence round the essay; (β) a black pulverulent sublimate, just above it, which, heated with O.P., evolves the garlic odor, and treated in $\text{H}\beta$ gives a metallic film on the surface of the glass; and (γ) a copious white pulverulent sublimate of AsO_3 , which vanishes

* Paragraph (93).

† *Vide* also my paper on *Jeypoorite*, 'Pro. Roy. Soc.,' vol. xxi., p. 292.

when touched with O.P., being probably converted into the invisible acid exhalation which is always first eliminated from this class of metals by heat.*

In roasting an arsenide on aluminum plate, so as to get rid of the greater part, if not all of the arsenic, three P's only are required, viz. Patience; a Peroxidizing Pyrocone; and Powdering the mineral. The operator converts it into paste with water, between agates, roasts a cake of this paste on the plate with a *long* P.P., taking care never to allow the temperature to rise high enough to fuse the mass: the cake is turned over, and thus roasted on every side, re-crushed with water and again roasted, until no sublimate is afforded on the shining aluminum.

The pyrochrome of arsenic is a pale greenish-blue (Fβ, d).

(a) Arsenic acid fuses on this apparatus, but, losing its water of crystallization, resists even a strong O.P. to a considerable extent, glowing slightly. When, however, the cake thus formed is turned, and the part which had been resting on the aluminum plate is exposed to O.P., it rapidly fuses again, giving off fumes of a white vapour, which is inodorous, but covers the plate and steel forceps with a more moist and less white sublimate than that of AsO_2 . This is shown to be arsenic acid volatilized intact, by the application of moist blue litmus paper, which proves it to be a *strong* acid. This sublimate is something like the metallic one of mercury, and, like it, vanishes in O.P., but is easily distinguished from that by not congesting into balls on being scraped. On the first application of O.P. to this acid also, the rainbow-like halo is formed above the essay on the shining aluminum described above, which seems due to a thin coating of metallic arsenic, and is not produced (so far as my experience goes) by any other oxide except mercury. Fluorine also gives it, from which it is easily distinguished.† The above seems a better, because more rapid and certain method of dealing with arsenates than the reduction process mentioned by Plattner.‡

(b) If a piece of native arsenic be gently heated in a small corked test tube until the enclosed air is decomposed by the arsenious acid formed, and if then the tightly-closed tube be so heated over a spirit lamp that the cork is slightly burned inside, which in ordinary air would form carbonic acid, the glass of the tube round the arsenic is corroded even more violently than by hydrofluoric acid, the whole inner surface being rendered semiopaque, like ground glass, while large transparent blisters are formed as by violent heat, although the heat applied in my experiment (never nearly amounting to redness) was altogether about the cork.

(237). ANTIMONIDES.

Pure Antimony *per se* fuses on aluminum plate in O.P., and evolves two

* Paragraph (129, f).

† Paragraph (213).

‡ Page 453.

slight sublimates, black and white,* after which it is not much more acted on than tin is. The chemically prepared white-yellow teroxide does not fuse, but is slowly volatilized into the white sublimate. If any yellow is perceived, there is an adulteration, probably of sulphur, as neither lead nor bismuth afford that color on the bare plate. Antimonial minerals, especially when combined with sulphur, evolve both the black and white sublimates copiously even on the bare plate, after a portion of arsenic (if that be present) has been volatilized, but contemporaneously with a second portion. This fact may be observed, for instance, in treating the mineral *Tetrahedrite*, in which, after the first O.P., the antimonial sublimate (α) is found (by the test to be presently described) over the arsenious sublimate (β); but on again heating, arsenious acid is smelled strongly, while antimonial peroxide is also deposited. This latter sublimate (α) is detected, even when in such minute quantity that burnished steel pliers on which it is deposited require to be held downwards against the light to enable a sublimate to be perceived at all, by the property it possesses of instantly turning black when touched with O.P., which seems to reduce it to suboxide. The white lead sublimate above mentioned† turns a deep brown, nearly black, when similarly touched, but not till after some time; besides which, the latter never rises so high up the plate as the former.

In a mechanical superposition of these white sublimates, (α) over (β) on aluminum plate turns black momentarily in O.P.; *then white again*. On steel it partly volatilizes, and partly turns black; but when thickly deposited, a metallic-looking crust is left. (β) over (α) is (curiously) deposited, although itself white, as a dark film or layer, and the antimonial sublimate underneath does not blacken completely or quickly as it does *per se* in O.P. In a glass of $\ddot{\text{H}}\ddot{\text{P}}$ the black sublimate of antimony fuses to a metallic ball, with an icy mass round it, which is very characteristic of antimony, emitting the peculiar lucifer-match smell of antimony and phosphorus,‡ while the black arsenious sublimate forms a metallic-looking film.§ It is not necessary in this qualitative examination for antimony in minerals to separate that oxide from lead by boric acid, as recommended by Plattner,|| for in this apparatus the plumbic white sublimate does not rise, even when the essay is placed on a mortar, to the steel forceps, like that of antimony, while it can be easily proved that, though metallic lead is dissolved in $\ddot{\text{H}}\ddot{\text{P}}$, the chemically prepared *oxides* are not, but form an opaque white enamel, which antimonious oxide also does. The pyrochrome of antimony is a pale green ($\text{E}\beta, d$), which readily distinguishes it from that of arsenic ($\text{F}\beta, d$), but when the former is combined with sulphur these are almost identical.

* Paragraph (129, f).

† Paragraph (234).

‡ Paragraph (129, b).

§ Paragraph (236).

|| Page 426.

(a) In an $\text{H}\ddot{\text{B}}$ glass the combined sublimate of antimony fused with lead affords on cooling a milk-white glass only given besides, of the volatilizable metals, by arsenic similarly treated.

(238). TELLURIDES.

It seems difficult to understand why Tellurium should be classed by the chemists as a non-metal from the mere reason of its supposed incapability of forming a "basic oxide." It is much less volatilizable than arsenic is, and fuses to a ball on aluminum plate, which that cannot do. Although it affords a sublimate there without charcoal, so does zinc, and it affords a bluish-green pyrochrome very like that of zinc, but its sublimate is more volatilizable, as it slowly disappears in O.P. It burns with a smell at first very like that of selenium, though perhaps not quite so odious, but in cooling, the smell changes to that of burning hair or skin. On aluminum plate *per se*, it affords a halo, having a black or greyish-black nucleus (which is probably the required basic oxide), with a white border, which latter rises three inches, and slightly coats the steel forceps like antimonious acid, blackening also in O.P. as that does. The scraped off white sublimate instantly turns black on the application of a hot $\text{H}\ddot{\text{B}}$ glass, but not of an $\text{H}\ddot{\text{P}}$ one. The smallest portion, however, taken up on the latter, causes the glass to become deep brown on cooling, and attacks the platinum wire far more forcibly than arsenic. Plattner says,* that the telluric sublimate, "which disappears under RF, imparts to the flame in presence of selenium a bluish-green tinge. Should the horseradish odor be also perceived, this is a certain indication of selenium."

(239). BISMUTHIDES.

According to Plattner† the most intricate combination in which to detect a trifling quantity of Bismuth is in lead, containing also antimony. In such a case that author recommends the operator first to "free the compound from antimony, if present, by treating it for some time on coal in OF." The combined sublimes (of lead and bismuth) are then to be scraped off the charcoal, and treated in a bead of microcosmic salt on charcoal with a piece of tin, when the oxide of bismuth (or, antimony) is precipitated, and the bead becomes dark grey. Now, although this procedure seems very simple, it is open to the objections, (a) that antimony is not so easily got rid of, as it possesses about the same volatility when supported on charcoal, under heat, that bismuth does; and (b) it is out of the ordinary course of analysis; for an operator has here no indication in the plumbic sublimate to lead him to treat it in Mic. salt for bismuth. On burnished aluminum plate, however, bismuth is rapidly and certainly distinguished from lead, when present even in trifling

* Page 455.

† Page 364.

proportion, as, for instance, in *Rammelsbergite*, ground up with galena, (α) by the metal "sweating" out of the fragment, which only happens *also* in the case of tin oxide, and that not nearly so quickly; (β) by the black sublimate round the essay not being nearly so thick or velvety as that of lead; and being, unlike that, movable by O.P., while the spot where the essay has been is covered with a thin grey coat; and (γ), by the bismuthic yellow sublimate, when a (C) mortar is placed between the essay and the plate, being much more spread over the plate than the plumbic on, which is found only directly opposite the essay. From antimony it is at once distinguished by the fact that the brownish-white sublimate of the two together on aluminum plate is rendered instantaneously snow white by a momentary P.P., while the white of either alone, or of lead, is unchanged by that. An alloy of lead, antimony, and bismuth affords the following characteristics when heated *per se* in O.P. on aluminum plate. (α) A "sweating" of bismuthic globules takes place *near* the O.P. (β) The black sublimate round the essay is moved by O.P., and is covered in the part under it when it has been removed with a grey film by O.P. (γ) The steel of the forceps is covered with a rusty-looking film, which becomes gelatinous when dipped in water; a very characteristic reaction. All these indicate bismuth. (δ) The white sublimate round the black one turns black instantaneously in O.P. (ϵ) The essay is covered at top with a black unlustrous film; and (ζ) a pale green pyrochrome. These show antimony. (η) With a (C) mortar slipped between the essay in O.P., after emitting a combined smoke of Sb and Bi (as may be proved by the film on steel turning orange-brown by a momentary O.P., with water gelatinous, and when scraped with the back of a penknife black), it gives the yellow plumbic sublimate (exactly opposite the essay). (θ) Squeezed in the (α) forceps the essay becomes flattened, and is not crushed. These indicate lead.

(α) The following is also a very characteristic test for the presence of bismuth. The essay, unless containing lead (when it may be fused *per se*), is to be fused with that metal on a keyhole mortar over aluminum plate, a little of the sublimate gently scraped off with a penknife, and treated with O.P. in an HB glass, to which bismuthic sublimate communicates a yellowish-brown semi-transparent appearance quite unique.

(240). HYDRARGYRIDES.

Mercury in any combination, but necessarily also in not less than a certain quantity, affords the well-known characteristic white sublimate on being heated, which, though it appears pulverulent without a lens, is in reality composed of myriads of minute balls of mercury (as may be discerned by a powerful microscope), which can be scraped into larger, and therefore visible, balls,

with the back of a penknife. When, however, only a very small quantity of mercuric oxide exists, especially in combination with sublimate yielding oxides, this indication is not given, and this is precisely the condition of knowledge in which the present students in blowpipe analysis are left. But mercury affords another, and in the proper sense of the word, the only real sublimate, before it is driven bodily upwards in minute balls by heat. This fact may be ascertained by heating a ball of mercury the size of a pea on burnished aluminum plate in a very weak O.P. The metallic sublimate still covers the greater part of the surface of the plate, but round the cooler edges will be observed, through the lens, longish white, filamentary fragments, with round sides like miniature macaroni, so light that they seem alive as they move by otherwise insensible currents of air. This sublimate can be brushed off with a smallest size hair pencil into a bottle. Quicksilver heated in O.P. on aluminum plate, although its fluidity seems by no means decreased, loses its property of preserving a spherical shape, the under part sticking *pro tem.* to the aluminum. The upper surface is covered with a deep brown oxide, while a beautiful reddish-orange pyrochrome is perceived, while the several sublimes are deposited immediately round (above) the essay in the following order: (α) Brown-black. (β) Golden yellow, shading off to yellow. (γ) An iridescent halo like a double rainbow, with the colors thus arranged from the essay: red, green, red, yellow, green, blue, red, yellow, blue; the last outside of all, very broad, and shading off into violet. When the plate was held slanting against the light (β) appeared pea-green.

(241). PLUMBIDES.

In qualitative examinations made with reference to this useful metal (Lead), the operator has generally one (or two) of three objects in view. (α) He wishes to detect adulterations of antimony, bismuth, &c., with a view to the ulterior determination of the amount of lead. (β) He wants to see if the lead is argentiferous; and (γ) The lead is to be detected as an adulteration. It is obvious that the operations (α) and (β) or (β) and (γ) may be combined, and the following essay of Freiberg *Galena* is an illustration of those:

(1) Decrepitation; cured by boiling the fragments on platinum foil.*

(α) On first gently heating through the platinum foil, a slight white efflorescence.—[Trace of Zinc.] Table V. (11) (63).†

* Paragraph (160).

† Plattner, whose keen observation so little has escaped, seems to have seen this reaction, but not to have guessed the cause of it; for he says (page 343), "*Galena* and *Bleichweiss* usually decrepitate strongly in the closed tube, while a trifling white sublimate is not unfrequently formed, which, however, appears to be only sulphur." He could have easily proved that it is *not* due to sulphur by thus heating almost any other than a lead, zinc, or tin sulphide without getting a similar result, unless it contain zinc, which *Galena* seems generally to do.

- (b) On first gently heating through the platinum foil, pungent smell of SO_2 .—[Sulphur.]
- (2) Treated with O.P., a piece the size of (O) *per se* on aluminum plate.
 - (a) Velvety black halo, with white above, turning black in O.P.—[Antimony.]
 - (b) A brownish sublimate on steel, not volatile, and not blackening with O.P.—[Bismuth.]
 - (c) Touched with O.P., (a) gave a brown and then yellow halo.
 - (d) Touched with P.P., the yellow sublimate vanished.—[Antimonic or Arsenic Sulphide.]
 - (e) Black sublimate easily wiped off.—[Antimony, in absence of Arsenic.]
 - (f) The essay itself shows white metallic spots through the black crust of Suboxide.—[Lead.]

N.B.—These show so white against the black, that a tyro might fancy them due to silver.

- (g) A pale blue pyrochrome.—[Antimonic Sulphide, or Suboxide of Lead.]
- (3) Strong table O.P. directed on the same essay, upon the bare aluminum.
 - (a) A faint sublimate on steel, blackened by O.P.—[Antimony.]
 - (b) Round essay; black halo, with white above, constant in slight O.P.—[Lead.]
 - (c) Blue pyrochrome, a deeper-toned blue.—[Lead.]
 - (d) Black sublimate not wiped off.—[Lead, in absence of Bismuth.]
- (4) On charcoal mortar on aluminum plate in O.P.
 - (a) A thick brown-yellow halo, opposite the essay.—[Lead.]
 - (b) Black halo underneath, against the essay, bordered with white, both constant in slight O.P.—[Lead.]
 - (c) Several small balls of white metal in (a).—[Loss of metal.]
 - (d) The essay squeezed in (a) forceps, very soft and quite malleable.—[Lead.]
 - (e) The essay, paler than lead.—[Probable presence of Silver.]
- (5) The essay taken up at the bottom of a bead of $\ddot{\text{H}}\text{P}$ on platinum wire, in O.P. Bluish-yellow, creamy streaks.—[Oxide of Silver.]

(6) A piece of the same ore the size of a small pin's head, afforded, when treated directly on charcoal on aluminum plate in a strong table O.P., one of the most beautiful sublimates I ever saw. It was in the shape of the eyes in a peacock's tail. Outside a pure white, shading off to cerulean blue. Under this, spread in elliptical form, a delicate rose-pink, due to suboxide of silver. Inside

of this pink, and corresponding to the centre of the peacock "eye,"* an emerald green,† the result, as I suppose, of the effect of the yellow plumbic oxide seen through the blue sublimate, caused by white thinly spread over black. Immediately under the green, a bright yellow (PbO), and lowest of all, black. Scraped off gently with a penknife, the under part of all these sublimate, except the black, was found to be snow white.

(a) Treated in like manner, *Boulangerite* affords, besides sulphur, antimony and lead, evident indications of the presence of small quantities of zinc and silver. *Bournonite* gives these also, and on being finally treated on bare aluminum plate with an equal bulk of $\ddot{\text{H}}\ddot{\text{B}}$ in a strong O.P., copper shows itself very distinctly in the under part of a piece the size of a small pin's head; the rest of the ball, when squeezed in the (α) forceps, being brittle with a crystalline fracture, and not malleable; from which it would appear that good lead could not be easily manufactured from this ore.

(b) A very small speck of plumbic oxide, as prepared by chemists, in an $\ddot{\text{H}}\ddot{\text{B}}$ glass under O.P., renders it opaline, and a large addition of fresh $\ddot{\text{H}}\ddot{\text{B}}$ will clarify it, but the slightest further addition of lead oxide renders the glass milk-white and opaque on cooling, even after a long P.P. It is thus easily distinguished from argentic oxide.‡ The yellow pyroxide or sublimate of lead, on the contrary, as obtained by treating *probir blei* on charcoal over aluminum plate, and scraping off the halo formed, rapidly dissolves in an $\ddot{\text{H}}\ddot{\text{B}}$ glass under O.P., leaving it transparent and acromatic, but vitreous, and the reason of this is evident, for the powder when first treated instantly changes to a film of metal. H.P. does not produce a precipitate in this glass, nor when potassic carbonate is added. Lead oxides change the green $\ddot{\text{H}}\ddot{\text{B}}$ pyrochrome to greenish-blue ($\text{F}\beta$). The brown pyroxide (obtained by treatment with P.P.) forms in $\ddot{\text{H}}\ddot{\text{B}}$ at first opaque white fragments, which in continued O.P. become lead-like balls, which are slowly dissolved, rendering the glass vitreous but clear, not opaline. In an $\ddot{\text{H}}\ddot{\text{B}}$ glass, the pure plumbic sublimate dissolves, under O.P. applied to the opposite side from that on which the essay is taken up, to a clear refractive glass which is unaltered by H.P., hence its value for testing oxides which precipitate, &c., in H.P.

(c) Lead contained in small proportions with much antimony is best distinguished by treating the combined white sublimate formed by O.P. with a strong, not too broad H.P., when a round black stain is left on the aluminum

* The blue color of a "peacock eye" is produced only by the H.P. sublimate of molybdic acid — Paragraph (235). The term is here again used merely to denote the general resemblance.

† I never before saw a green sublimate. This had quite as bright a tint as that given to the zinc sublimate by cobalt solution.

‡ Paragraph (243, c).

by both; but that of lead is iridescent and metallic looking, while that of antimony is still pulverulent, and a greyish-black.

(d) The pure lead sublimate, as obtained on aluminum plate by the total volatilization of a pin's head fragment of the Freiberg *probir blei*, under O.P. on a charcoal mortar, consists of a halo about $\frac{3}{4}$ ths of an inch diameter, with a small black nucleus or eye. (α) Next above that, greenish-yellow, with small orange balls. (β) Above that, coffee brown, shading to yellow. (γ) Above that, white. (δ) At the lower edge of the brown was an extremely faint shade of pink showing a minute trace of silver. In H.P. all these are blended into a greenish-black color.

It is of great importance to pay attention to the pure lead halo on aluminum plate, for many other metals, as, e. g. chromium, Vanadium, and silver, are most rapidly recognized by the difference the halo of their lead combination shows to this. In P.P. the pure lead halo turns (α) coffee brown; (β) unchanged, the orange being apparently due to the presence of zinc oxide; (γ) unchanged; (δ) unchanged, turning greenish-brown on first heating, but this shade vanishes and leaves the surface white.

(e) The student of the pyrological reactions of lead will do well to read carefully the instructive, elaborate, and luminous article on "Lead Fume," in Dr. Percy's 'Metallurgy.'* The analyses there cited and given show that a good deal yet remains to be done in the way of a careful examination of this substance, and especially as regards the quantitative ratio it bears to the alloy or ore evolving it under pyrooxidation.

The author criticizes, justly perhaps, but rather severely, a description of "Lead Smelting in India," communicated to a local periodical of that mis-governed Imperiality, by Captain Dixon, of the Bengal Artillery, so long ago as 1831.† The captain is represented to have been "neither a mineralogist, geologist, miner, nor metallurgist;" to none of which titles, being a captain of artillery, he probably aspired: yet his description seems meritorious, or it would not have occupied four pages of Dr. Percy's work. Captain Dixon had left the regiment, or died, before I joined it, and I had not the pleasure of his acquaintance. He certainly should not, in a description, however "popular," have mistaken *Steatite* for *Chalk*; but many besides myself will vouch for the correctness of this account: "Ore occurring in beautiful crystals, called by the natives *Surma*, and sold, as taken from the mines, as antimony. Lumps of this ore, weighing from 2 to 3 lb., have been used as antimony for laboratory purposes in the Ajmeer Magazine, in their natural state." Upon this statement, Dr. Percy comments: "The author was evidently no mineralogist; but it is clear that the substance to which he here refers is *Galena*, though it may be very puzzling to

* Pages 434-438, inclusive, in the volume on Lead.

† Page 293.

explain how *Galena* should have served as a substitute for sulphide of antimony in the Agra Magazine."

Now, Captain Dixon seems, in the above account, not to have stated that *Galena* is *Stibnite*, but merely that the Indian Government bought it as such—and so they did (for fifty years, as I was unguardedly informed by the Principal Commissary of Ordnance, Colonel Lewis): so they did, even after the Government became Imperial, as the following anecdote will show. They bought it (I believe) chiefly for "fireworks,"* in which manufacture *Galena* answers in some sort for *Stibnite*, as it does for blackening eyelids, &c.: though it could not have been required for the latter purpose, even by the last Indian Secretary of State.

In 1862, I was under a promise to a friend (Mr. Brereton Todd), of Falmouth, Cornwall, to look out, on my return to India, for "antimony ore," a piece of which—undoubtedly pure—he showed me before leaving Cornwall, in 1861, which he assured me had been found at Futteghur, and could be put on board ship in Calcutta at 4*l.* per ton. I ascertained afterwards that the unprincipled agent he employed had obtained this specimen of (Borneo) *Stibnite* in the Calcutta Bazaar, and forwarded it to him as from Futteghur. Still on the look out for *Stibnite*, I observed one day (A.D. 1862), in the 'Punjaub Government Gazette,' an official periodical, the following sentence in the report of their geological or mineralogical surveyor:—"Antimony ore exists in almost any quantity." The phraseology of this might have made me suspicious, but, in those days, the word "Government" tagged to a man's occupation weighed with me almost as much as the infernal *Galena* weighed, which was sent (post *not* paid) to me at Calcutta from these prolific "antimonial" mines of the Punjaub, and for the carriage of which I had to pay, of Her Majesty's rupees, 9, or 18*s.*! I afterwards obtained a specimen of extremely pure *Stibnite* from Kulu, in the Himalaya, and sent it to Mr. Todd. This *contretemps* did not quite quench my zealous search for *Surma* (which, by the way, is Hindustani for *manufactured* antimony), and one day, nearly a year after, at Meerut, I asked a Kashmir merchant, from whom I had purchased some *Lapis lazuli*, if he had any ore of *Surma*. "Certainly," he said, and showed me the inevitable cubes of *Galena*. I melted one of these on charcoal with a blowpipe, and squeezed the resulting lead with forceps, to show him that, being malleable, it could not be antimony. I also melted before him a piece of red translucent *Pyrargyrite* from a Freiberg cabinet (he guessed it to be a *Garnet*), and his face, on witnessing the ball of silver appear, was a study for Rembrandt or Hogarth. "Sahib," he said, "if you will come into the Maharajah's dominions (those of Rumbir Singh, Rajah of Kashmir), he will give you any *tullub* (salary) you require." I had long wished to see Kashmir, and, half seriously, I wrote at his request a note to the Rajah, which the jeweller,

* The old designation of a second Lieutenant of Artillery was "Lieutenant Fireworker."

being, as he said, his *moostoofee*, promised to deliver into the royal hands. I said that, understanding I might be useful to His Highness as a mineral surveyor, I was willing to undertake the duties of such for him if he would guarantee me a house to live in, and the same salary I would receive as a battery captain, which I then hoped shortly to be, viz. 1000 rs. (100*l.*) a month. He promised this, and I had the extreme mortification of seeing, some months after this occurred, in the 'Government Gazette,' that "His Highness the Maharajah Rumbir Singh, of Kashmir, having applied to the Government of India for a mineral surveyor, on a salary of 1000 rs. per mensem and a house, Mr. So-and-so, of the Geological Survey, had been appointed" to this delightful and lucrative post. The jeweller, when convinced that his *Galena* could not be an ore of antimony, looking cautiously round, said, "Look here, Sahib, I have got here some *ussul Eranee Surma*" (genuine Persian antimony), and then took out of many folds of his *kummerbund* a black mineral, which I treated with the blowpipe without even looking at it. To my surprise no impression was made, and then, looking more closely, I soon found it to be *Graphite* as pure as ever came out of Borrowdale, in Cumberland. [Here is a hint for Baron Reuter!] I purchased from him this specimen, which I still possess.

(*f*) It is obvious that, if any oxide of lead could be obtained positively, or even moderately pure, as a reagent, it could be more easily and intimately mixed with the ground assay for the purpose of examining that by the process of "lead fuming" than the *probir blei* of Freiberg, and would, therefore, be even more useful than that. I am sorry to say, however, that I doubt the possibility of obtaining moderately pure lead oxide, at present, in London. The following is an examination I made of brown peroxide of lead purchased from a well-known firm of the highest class, as being especially pure. Fused in a keyhole mortar on aluminum it afforded, with much effervescence, an apparently pure lead sublimate,* but some of the white border of the halo, scraped off and treated in *H₂B*, only afforded, even with a large excess of that, an opaque white glass, showing evidently that antimony, arsenic, or some such oxide was present, and rendering the reagent, of course, useless for these purposes. Treated with O.P. on aluminum without charcoal, the brown powder fused to litharge, but could not be reduced beyond that, even by H.P. A white border to the black nucleus was afforded, a great deal too copious for that of pure lead,† which blackened strongly in O.P., showing that there was a considerable quantity of antimonial oxide present. An antimonial sublimate, blackening in O.P., was also deposited on the steel (*θ*) forceps, 2·5 inches above the assay. But this was not all: the *probir blei* sublimate deposits from charcoal on aluminum a white border to the halo, which at first turns slightly brown in a short P.P., but if this be continued,

* Paragraph (241, *d*).

† Paragraph (123, *g*).

vanishes, never to return, and the border then becomes black-brown in O.P., which last color is apparently unalterable. The lead reduced from this "pure" peroxide under similar conditions, on the contrary, affords a white border which can be changed to black-brown and back to white by alternate O.P. and P.P. In $\ddot{H}\ddot{P}$ also this produces a glass which is yellow warm, indicating the probable presence of iron sesquioxide.

(242). SUBVOLATILE METALS.—The term "subvolatile" is used to distinguish metals which do not afford a sublimate when treated with O.P. *per se*, even on charcoal over aluminum, but when fused thus with proof lead give a compound plumbic sublimate, the reactions of which in $\ddot{H}\ddot{B}$ or $\ddot{H}\ddot{P}$ betray their presence. The fact above narrated,* that the most oxygenated, or, as it is usually termed, the "acid" oxide of some metals, is also the most volatile, especially exemplified in the case of antimony, led me to examine the sublimate of plumbic Vanadate (or *Vanadinite*) on aluminum plate, in the hope of finding this "acid" oxide sublimed with the lead; and in this expectation I was not disappointed.† The sublimatical halo formed is, it is true, chiefly distinguished from that of pure lead in outward appearance by the presence of silver, which converts the yellow sublimate of the former into a truly beautiful red-orange (*Aa*),‡ which I at first attributed to Vanadic acid, but soon found that the picture contained a representation of *both* these subvolatile metals; for the upper or white part of the sublimate scraped off and applied to an $\ddot{H}\ddot{B}$ glass with a few specks of potassic carbonate, gave the delicate blue so characteristic of VO_3 ; while the white part of the sublimate of plumbic chromate, though through a lens not differing from the former, afforded in the same reagent the here insoluble green fragments of chromic sesquioxide, and the sublimate obtained from a fusion of the two metals with lead produced in a similarly composed glass *both* these reactions, the glass being blue and transparent, with green fragments of chromic sesquioxide floating in it.

(a) The *rationale* of the process seems to be, that Vanadate, chromate, titanate, stannate, tantalate, &c., of lead is formed, and subliming, may be scraped off the aluminum as an impalpable powder. The acid element of this combination is generally either insoluble in $\ddot{H}\ddot{B}$, or if soluble, chromatic; while the base (i.e. plumbic sublimate) dissolves rapidly and easily to a colorless vitreous glass.

(b) Any unprejudiced chemist will favourably compare this simple method with the complicated, long, and not nearly so certain process of fusion with "bisulphate of potash," nitre, carbonate of soda, &c., as detailed by Plattner.§

* Paragraph (234).

† Paragraph (245, b).

‡ Paragraph (245).

§ Pages 419, 438, 442.

(c) DECOMPOSITION OF "NOBLE METALS" BY THE PROCESS OF LEAD FUMING.—After Paragraphs (242, a, b) were written, I found that gold and even platinum are at once decomposed by fusion with lead, as above described, and yield a pyroxide which accompanies that of the lead up the aluminum plate in sublimation, and is to be found in its "fume," generally in the highest part of the halo, i.e. the white border. This fact is easily proved by treating this part of the fume in a glass of \ddot{H} , under P.P., when, especially in the case of gold, a beautiful violet-red ($H\gamma$) tint flushes over the glass just as that is becoming cold. The plumboplatinic glass has the same tint, but is much more light in tone, and must be kept in a longer P.P. than the first, as the least tendency to reduction spoils the color which cannot then be reproduced. This faintness of tone in the color of the platinic glass cannot be due to paucity of the oxide thus sublimated, for the application to it of H.P. produces so conspicuous a precipitate, that it first becomes muddy, bluish by transmitted light, and then opaque, the pure lead sublimate remaining transparent and colorless under all circumstances in \ddot{H} . But this very fact supplies an excellent and decisive distinction between the discrimination of the presence of gold or platinum in the essay, and seems to me, therefore, to further show the value of this simple, novel, and rapid method of analyzing the "noble metals." Still, however, a hypothesis remains, that the platinum foil used by me contained a trace of gold; and I cannot disprove such an assumption, except by stating that it was purchased from the celebrated firm of Messrs. Johnston and Matthey, and that I here assume it to be pure. What the *rationale* of this ascension of pyroxides of these two "noble metals" with that of lead in sublimation is, must be explained by better chemists than myself. I have stated novel but natural facts, as any operator can prove to his own satisfaction; it is for those whose names carry sufficient weight to *artificise* these facts, that is, to reduce them to recognized chemical "laws" with which at present they seem at variance. Is the plumboplatinic or plumbauric sublimate a chemical or mechanical combination? If the former, which is the basic and which the acid constituent? If the latter, how are we to account for the oxides of two metals, each of greater specific gravity than lead, being thus carried *in ascensum* by the oxide of that? It would certainly seem* that plumbic acid is formed by the sublimation of lead, and capable of forming a salt with any sublimated oxide able to act as base, for it is quite impossible that the alkaline plumborate ball could be a mere mechanical combination; but, on the other hand, what is the constitution of the sublimate in which Vanadic, titanitic, chromic acid, &c., is evidently present? The truth probably is, that several oxides of lead are formed by simple fusion of the metal in O.P., but can only be distinctly recognized when spread over aluminum plate.

* Paragraph (220, b).

(1) There is the "dull velvety black and perfectly homogeneous" nucleus of the halo which, when prepared by heating gently oxalate of lead, is, according to Dr. Percy,* "a definite dioxide," though the Pb_2O said to have been prepared by Berzelius by heating lead below its melting point, is denied existence. (2) There is plumbic protoxide, which, according to the work cited,† although "a powerful base, also acts the part of an acid towards strong bases, such as potash, soda, baryta, and lime." The average percentage in this substance in three samples of lead fume analyzed in Dr. Percy's laboratory‡ is 51.83. (3) The sesquioxide (Pb_2O_3) "described by Winkelblec as a fine amorphous red-yellow powder,"§ may be present; as also (4) red lead (Pb_3O_4) which "has a fine bright red or orange color;"|| and finally, (5) plumbic peroxide (PbO_2), described by the same author as having "a dark chocolate-brown or puce color," which again is said¶ to possess with acetic acid, at any rate, basic properties. The algebraical manipulation of the novel facts I have recorded must, in short, be left to the ingenuity of the modern chemist; it is sufficient for us that they *are* facts, and that can be proved.

(243). ARGENTIDES.—A globule of pure silver (reduced from the nitrate) treated on charcoal in a moderate O.P., loses 10 per cent. of its weight in one minute and a half. This is a fact worth the consideration of those who are in the habit of obtaining silver solely by the process of cupellation. I find the following in a modern work on 'Metallurgical Chemistry,' lately published by an eminent London firm: "Silver is not capable of undergoing oxidation in the air, under any circumstances." Now it is not only liable (almost as much so as lead, when combined with that in a mineral) to be oxidized by even a moderate degree of heat; but, when supported by charcoal or bone ash, to be sublimed by a strong O.P., like mercury, in the metallic state; only the balls driven off mechanically by heat are not nearly so minute as in the latter case. The truth of these facts can easily be tested by an operator, and there can be no doubt of their existence. By far the most delicate indication, indeed, of the presence of silver in a mineral is the violet-red or "ruby" ($H\gamma$, d) sublimate or oxide (brown hot) spread over aluminum plate when quite cold, in the upper part of the halo formed behind a charcoal mortar by the essay treated in O.P. When this appears, the operator may be perfectly certain that silver or gold** is present, and a very fair guess may be formed of the quantity by its copiousness and *tone* of color, if he has previously established a standard by the volatilization of a known quantity of silver fused with lead. The sublimate of selenium is copper-red; those of arsenical or antimonial sulphides, orange-red; of a mixture of

* 'Metallurgy of Lead,' p. 11.

|| Page 24.

† Page 16.

¶ Page 25.

‡ Ibid. p. 451.

§ Ibid. p. 23.

** Paragraph (243, k).

zinc and lead treated with O.P., red-orange; but the dullest observer cannot mistake these or any other, except that of gold,* for the rose or "ruby" sublimate of silver. It is certainly astounding that this extremely beautiful and important (in a pyrognosticating sense, as it ought also to be in a commercial one) pyrooxide of silver should be utterly unmentioned in English chemical works. Plattner says of it,† "Compounds of silver with metals volatile at a high heat, yield a coat on charcoal. After nearly the whole of these metals have been volatilized by long blowing, the coat becomes reddish to carmine-red from the oxide of silver, if there is not too little of that metal present. This reddening of the coat is highly characteristic, and may always be regarded as indicating silver." From this description it seems that, in the treatment on charcoal, either the first cloud of "ruby" oxide is reduced by the glowing charcoal, and disappears in its cracks as minute metallic globules, or that the red "coat" is covered by a white antimonial or plumbic one in the first stage of volatilization on charcoal, when these latter sublimates are extremely copious; for the burnished aluminum plate, which betrays the faintest indication of sublimates, and from its angular shape receives them in the natural order of their ascension, shows the "red coat" not only very early in the process of oxidation, but when there cannot be more than a mere trace of silver present; as, for instance, in *Pyromorphite*, *Boulangerite*, *Bourmonite*, *Vanadinite*, &c.‡ *Galena* affords quite a copious sublimate of "ruby silver," and that from a minute ball which was by no means exhausted.§

(a) A ball of pure silver, although treated *per se* on charcoal over aluminum, exactly in the same manner as the alloy, yields scarcely any pink sublimate, and the reason of this seems evident; for instead of that, minute balls, and even, in a very strong O.P., actual splashes of metallic silver are found on the aluminum plate, so that silver, if unalloyed with other metals, especially with lead, or not combined with sulphur, sublimes under O.P. *metallically* in a manner analogous to mercury, as above stated; but if the essay, while red hot, falls suddenly out of the charcoal on the aluminum, a pink and white ring forms round it.

(b) In testing for silver in all ores containing lead, a piece of the ore the size of a small pin's head is placed on a charcoal mortar, and that on aluminum plate, and (decrepitation having been overcome in a larger piece, as previously explained),|| the essay is treated directly with a strong O.P. Should it become

* Paragraph (248, k).

† Page 402.

‡ This rose tinge may be distinctly observed in sublimation, as above described, of English plate glass, which contains lead, fused with pure proof lead, the sublimate of which latter has been previously observed to be free from it.

§ Paragraph (241, b).

|| Paragraph (160).

so light that it is blown away by the blast (which often indicates iron), a piece of boric acid its own size is heated along with it. This holds it down, but does not prevent oxidation by covering the essay. If there is any silver in the essay, a pink sublimate will be almost immediately formed on the aluminum as part of the halo* at the back of the charcoal mortar. In an essay containing over 25 per cent. of silver, a ball remains, which is seen by its color to be that metal; but even the richest ores, if containing lead or antimony, afford the pink sublimate *first*.

(c) These sublimate should all be further tested by scraping them gently and separately off the aluminum plate with a smooth-edged penknife, and treating them under O.P. in an $\text{H}\ddot{\text{B}}$ glass. Silver oxide is thus at once recognized by its alkaline-like tendency to clarify the dim glass, and to reappear in that as a yellow creamy precipitate, i. e. in streaks, by the application of H.P. or fresh boric acid. In an $\text{H}\ddot{\text{B}}$ glass under O.P. plumbargentic sublimate presents streaks or "flecks" of yellow creamy matter, bluish by transmitted light. By H.P. a dense opaque precipitate is produced, which appears in the centre as a large ball, but if the saturated glass be clarified by P.P., and then cautiously treated in O.P., not too close to the point of the blue pyrocone, it will on becoming cold assume the very beautiful tortoiseshell red-yellow of pyragentic phosphate (bluish-yellow by reflected light), which is so characteristic as to readily permit the recognition of silver, even in presence of gold, cobalt, or other highly chromatic oxides. It is possible, but very difficult to retain the violet-red oxide of silver in fluxes.

(d) In an alloy of about equal parts of pure copper and silver, a thin, broad, metallic-looking pink sublimate of the latter metal is formed as a low halo, with a thin black nucleus, which might, however, be due to sulphur from the charcoal; but on the addition of a few specks of proof lead, a copious brown plumbic halo is formed, with a pure pink border, the essay ball being evidently a much more perfect alloy of silver with copper than it was before the addition of lead. Outside this halo is a white fringe, which, as it remains quite unaltered in even a strong O.P., is certainly not the sublimate of pure lead,† but seems also to contain silver; if so, this may be the argentic oxide which covers the fused essay like a shell, and prevents further fusion until that is driven off by a very strong O.P.‡

(e) These facts surely show that the principle on which is based the

* These compound argentic halos or sublimate on aluminum plate are so beautiful—imitating, as they closely do, the glorious tints of a morning or evening sky—that I wish I could here submit colored representations of them; and will, D.V., yet do so, should these modes of analysis be accepted.

† Paragraph (241, d).

‡ Paragraph (129, g).

cupellation of an argentocupreous ore by means of the addition of lead is defective, and results in a serious loss of silver? Von Engestrom, who was certainly acquainted with the process of cupellation, gives us a curious method* of extracting silver from lead without employing that, as though he were aware of the loss occasioned by it. He says, "This end will be sooner obtained, and the lead part quicker, if, during the fusion, the wind through the blowpipe is directed immediately, though not forcibly, upon the melted mass itself until it begins to cool; then the fire must be directed on it again. The lead will, by this artifice, be driven out in the form of a subtile smoke, and by thus continuing by turns to heat the mass, and then to blow off the lead, until no smoke is any longer perceived, the silver will at last be obtained pure." I tried this process by adding 13 mgrs. of pure silver to a cube of galena, and heating the ball on a charcoal mortar in O.P., but instead of the "subtile smoke," I found numerous metallic balls eliminated, which were proved not to be plumbic sulphide by squeezing them with the (α) forceps; that showed them to be perfectly malleable, and probably lead. But what still more surprised me, was a distinct pink halo at the commencement of the operation on the aluminum plate; so that, even at the very first heating, silver was evolved. It seems strange that, even in the present day, the long, tedious, and, unless very carefully performed, coarse and injurious process of cupellation should be used for the purpose of detecting silver in ores.

(f) A pin's-head ball of *probir blei*, the Freiberg reagent, affords, when thus treated, a faint pink tinge,† but it may, for all practical purposes, be considered to be free from silver.

(g) Traces of silver combined with copper, as, e. g. in *Tetrahedrite* (not the argentiferous variety), and *Spaniolite*, are not eliminated, and therefore not detected as a "ruby" sublimate, without the aid of lead, a few particles of which fused with the essay in O.P. cause a moderately strong pink halo to appear; a ball of copper being left. Green *Pyromorphite* almost at first, and the brown variety (*Braunbleiers*) after a short time, yield a pink sublimate.

(h) This violet-red (in trifling quantity pink) pyroxide of silver appears to be the highest or "acid" oxide, because its production, when fused on charcoal over aluminum plate with lead, is analogous to that of chromic, Vanadic, &c., acids. No plumbic ore, and few specimens of commercial lead, appear by this delicate test to be absolutely free from silver.‡

(i) Supported on an aluminum spoon, and a strong O.P. applied to an edge, pure silver does not fuse except on the edge, which as it burns affords a reddish-

* Sect. xxxix., p. 303, 'Cronstedt's Mineralogy.'

† Paragraph (241, d).

‡ Vide Paragraph (243, k).

orange (Ca) pyrochrome. Very strongly heated in the same way, with a high angle O.P., the edge affords a red-violet ($H\beta$) pyrochrome, which, if only partly produced, is pink, very much the color of the suboxide. This curious fact appears to have led to some erroneous conclusions, as silver has been used * for the purpose of "bringing out" the "red flame" better, in the case of traces of lithia, strontia, &c.

(j) Finally, it must be allowed that silver under O.P. is not such a stable metal as copper, and the fact that its oxide, in some measure, fluxes boric acid like the alkalies, is a curious confirmation of its (chemically) monatomic nature.

(k) Since the above was written, proof, so strong as to be almost convincing, has been received by the writer that the violet-red or ($H\gamma$) sublimate above described, and eliminated from all silver and all (but test) lead combinations, is due to the presence in these, of GOLD. The proofs are as follows: (1) Pure gold fused with lead affords† the ($H\gamma$) sublimate far more strongly than silver, and this latter changes in an hour or two to golden brown, while that remains unchanged; the former also, used as a pigment,‡ is pink; the latter brown. (2) A fragment of "pure" silver reduced from the nitrate, which has, when sublimated with test lead alone, afforded an ($H\gamma$) sublimate of considerable depth of tint, will, when alloyed with pure platinum, yield only the pure silver sublimate, which is a golden bronze color, and so thin that it appears (spread over the polished aluminum) semimetallic, but may be scraped off as a brown powder, and gives argentic reactions in $\ddot{H}\ddot{P}$ without any rose tint. If 1 per cent. of test lead be added to this alloy, this sublimate is much increased in volume, but auric pyroxide is then also eliminated, giving an ($H\beta$) *nucleus*, whereas, without platinum, it is found in the border. (3) Dr. Percy (the best English authority) says in a letter to me, dated 1st August, 1874, "I do not believe in the silver oxide which you mention, nor in certain experiments of Plattner, in which he supposed he had proved the existence of volatile oxide of silver. I have repeated his experiments, and have not been able to verify his conclusions." Now, the "red" sublimate afforded when silver is present is *undeniable*; is admitted, as will be detailed, by Dr. Percy's coadjutor, Mr. Smith; and when tested with $\ddot{H}\ddot{P}$ gives chiefly silver reactions. It follows, therefore, that though invariably obtained in sublimates where silver is present, it is not due to silver. But by (1) gold also affords it. The evident corollary seems, therefore, that it is due to gold, not silver; that all silver contains gold; and that all lead contains auriferous silver.

(244). CHROMIDES and Chromates. Chromic oxides, as easily recognized as any, when they exist in considerable proportion, by their unique property of

* Vide 'Select Modes of Analysis.' † Paragraph (a) in Art. on Gold. ‡ See the list of those.

communicating to fluxes under O.P. a green color, which, while hot, is red,* are difficult to detect by the present troublesome modes of previous fusion with soda, nitre, potassic "bisulphate," &c., and subsequent treatment with plumbic acetate, when they are not only present in small quantity, but likely to have their chromatic effect in fluxes overpowered by other oxides, as, e. g. in *Spinel*. Plattner gives us† a useful hint as to the suspicion of chromium in some minerals. "The minerals which are colored blood red by Cr_2O_3 , viz. *Pyrope*, and the spinel from Ceylon, have this peculiarity, that by simple heating in the forceps, they become black and opaque; on cooling, however, yellowish, or chrome green, then almost colorless, and finally, just as red as before heating. Those silicates which are colored red by chromium and iron together, become also opaque by heating, but assume immediately while cooling their original red color and transparency." To have completed this description, the writer should have told us the behaviour of minerals *not* containing chromium when thus treated, as many, indeed most, chromatic oxides dissolved to large extent in a flux, make it black hot, though regaining the bestowed color when cool.

(a) To detect traces of chromic oxide in a mineral, that should be crushed to paste between agates, some of the paste spread with a penknife both above and below a little proof lead in a keyhole mortar, and the mass fused in a strong O.P. on aluminum plate; some of the sublimate is then scraped off, and tested in $\text{H}\ddot{\text{B}}$, where the slightest trace of chromic acid (which must have risen with the lead sublimate, if present) is at once reduced to the state of sesquioxide, and shows itself as insoluble green fragments not unlike those of nickel oxide, but distinguished from them (a) by not assuming a metallic lustre in H.P., and (b), in affording a green, not a brown glass, by addition of potash as the latter does.

(b) Very minute traces of chromic oxide may be detected as above by direct application to $\text{H}\ddot{\text{B}}$ without previous plumbic sublimation, provided there is no substance present to form opaque balls in that reagent, and thus conceal the chromic reaction. Chromic iron, applied as a few specks of fine powder to an $\text{H}\ddot{\text{B}}$ glass in O.P. forms green fragments, but the green is of such a dark tone as to be only perceptible to practised eyes: the addition, however, of potassic carbonate until the flux has an evident alkaline reaction,‡ dissolves these, and the glass assumes a green color, which is red while hot.

(c) It is a curious fact that in the above case the chromic acid should

* Dr Noad says (p. 191, *Qualitative Analysis*) "(γ), The (borax) bead is green when hot, and green when cold; characteristic of sesquioxide of chromium." But Plattner, a better observer, says (p. 124, 'Probirkünst,' &c.) of a similar bead: "Heiss dunkelroth, wird bei volligen Erkalten, schon gelblich grün." Noad also calls this in another part of his book, "a bluish-green," which it certainly is not.

† Page 441.

‡ Paragraph (221, d).

have the effect of preventing the iron oxide from forming balls, which it does when alone; showing that the two are in a state of chemical, not mechanical combination. A red crystal of chromic acid, treated in $\ddot{H}\ddot{B}$ with O.P., is at once reduced to the green sesquioxide.

(245). VANADINIDES, Vanadates. Treated in O.P. on a charcoal mortar over aluminum plate, *Vanadinite* affords a perfectly different halo to that of pure lead similarly treated.* This fact led me to suppose that there are metals not volatilizable *per se*, except metallically as silver is, which are so when fused as above described, with a sufficient quantity of lead, and in this reaction lies much the most simple means of qualitatively examining them. Plattner gives † a formidable process for the detection of Vanadic acid in compounds, in which the substance (which must, however, be free from silica) is decomposed by fusion with nitre and soda, the solution "saturated with acetic acid," and treated with plumbic acetate, and thus Vanadate of lead formed, which might, according to this account, have been what was started with. The defects of this complicated method are shown by the admission that the only distinction of the simultaneous presence of chromic acid, is in the precipitate being "a darker yellow," and this is again made "paler" by sulphuric and other common acids. Von Kobell hit upon a more characteristic method of detecting Vanadic acid when he found that alcohol gave to the hydrochloric acid solution of a Vanadate an "azure blue," while that of a chromate remained green. This procedure, however, takes us into hydracid chemistry, and it is, moreover, by no means necessary to fly to hydrochloric acid to produce the reaction.

(a) Vanadic acid, obtained nearly pure by volatilizing the lead, &c., exhaustively from a fragment of *Vanadinite* on a charcoal mortar above aluminum plate, affords in $\ddot{H}\ddot{B}$, black opaque balls, when treated as small specks in a strong O.P.: large fragments of it remain unaltered, or in a glass containing a large quantity of lead, as in that derived by treating *Vanadinite* directly, it lies along the wire in a liquid state as a dark yellow-green enamel. In either case, a few specks of potassic carbonate under O.P. dissolve the contents of the glass, and clarify that, leaving it, when cold, a greenish-blue (F β). Chromic acid is easily distinguished here by its utter insolubility in this glass, where it remains as small, green, unaltered fragments. Iron oxide is separated by the following process.

(b) The halo of *Vanadinite* (or of Vanadates fused with lead) on charcoal above aluminum, is distinctively, a red-orange (Aa) shading off to yellow, white, and pale blue, like an evening sky. In $\ddot{H}\ddot{B}$ all these betray Vanadic acid and lead,‡ when scraped carefully and separately off with a penknife; but the

* Paragraph (242).

† Page 438.

‡ Paragraphs (241, d), (242).

(Aa) colored powder shows also silver oxide, to which its beautiful color, therefore, is chiefly due. If the Spaniard, Del Rio, who in 1801 discovered in this the oxide of a new metal, which he called Erythronium, from its giving blood-red spots to nitric acid, had known the above easy way of separating it from chromic acid, he would not have himself set aside his discovery.

(c) *Vanadinite* gives with phosphoric acid a glass of a much darker and more vivid green than the residue after sublimation on aluminum plate bestows; the last being a yellowish or "pea" green. The fact may be due, either to the chromatically heightening effect of lead oxide, or to the comparative absence of Vanadic acid.

(246). TANTALIDES, Tantalates; and COLUMBIDES, Columbates. Being unable to procure the pure acids in England, and thus, without standard reactions, I am forced to take these from the mineral *Columbite* (from Haddam, Connecticut), which, besides about 80 per cent. of these acids, contains, according to Dana, 16.4 of iron protoxide; 4.4 of manganese protoxide; 0.5 of tin oxide; and 0.1 of those of copper and lead. This mineral, crushed and fused with lead as above described, affords on aluminum plate a greenish-brown halo, with white border (no yellow), which in $\text{H}\beta$ gives a yellow glass, in cooling becoming deeper in tone and gelatinous, like the nitrogenous $\text{H}\beta$ one. There are also white undissolved fragments, like stannic oxide, but too numerous for 0.5 per cent. of that metal. The addition of potash, and then of zinc (suggested by Von Kobell's experiment with the latter and hydrochloric acid), only afforded a diluted yellow. A few specks of the crushed mineral applied *per se* to $\text{H}\beta$ yielded bluish-black amorphous fragments with white flocculent matter about them, like those of titanate acid,* but unlike those, these fragments have, in the pocket microscope, by reflected light, a brilliant semimetallic brown lustre, like *Avanturine*. A pin's-head fragment of pure (eggshell) lime produced a ball in this glass, colored greenish, evidently from iron protoxide (which might have been thus separated), for the *avanturine* fragments were as yet unattacked. After continued O.P., however, they gradually dissolved in the ball, giving it a fine red-brown color (2.1, Pl. III.), like that of *Cerite* in $\text{H}\beta$; proved to be not due to any manganese, by its remaining constant in H.P., and by the different color given to a calciboric ball by that oxide combined with iron, as in *Franklinite*. This red-brown ball, then, is an infallible test for these acids in combination; and they seem to be never found separate. A barytoboric ball containing a large trace of *Columbite* is colorless on cooling, so that these acids evidently interfere with the chromatic reaction of manganese in this reagent.

(a) The residue, after *Columbite* has been fused and sublimated with lead,

* Paragraph (247).

crushed and treated in $\ddot{H}\ddot{B}$ under O.P., gives a bead yellow while hot, colorless cold, like iron, but too bright yellow for that. On adding to the bottom of the bead a piece of zinc (which burns with a pure blue pyrochrome and a slight explosion), the bead becomes a very vivid orange while hot, and remains faint orange cold.

(247). TITANIDES, Titanates.—As little interferes with the beautiful titanic reaction (209), or purple, given by such minerals as *Rutile* in $\ddot{H}\ddot{B}$, and as the characteristic insoluble grey-blue fragments titanic acid affords in $\ddot{H}\ddot{B}$ cannot be depended upon when it is chemically combined in the essay, i.e. when that is a titanate, the above-described separating process of fusing the mineral with lead should be followed, when the titaniferous sublimate is treated as follows: A few specks treated in a momentary P.P. on $\ddot{H}\ddot{B}$ turn at first pale brick red; they then afford in O.P. a white opaline matter which dissolves with effervescence, leaving finally a few white fragments, which emit bubbles in O.P., but do not dissolve. The cautious addition of specks of potassic carbonate dissolves these fragments to a clear glass. If now this glass be treated with a short H.P., it becomes dark yellow, with brown streaks like tortoiseshell, and, with the H.P. continued a little longer, opaque white, with pale blue streaks like some kinds of marble, and the part next the platinum wire is altogether blue, indicating that the color is due to the formation of a lower oxide. If there is any quantity of titanium, the whole glass becomes opaque turquoise-blue. After a continued strong H.P. these glasses remain clear, but yellowish cold. This seems a unique and excellent test for titanic acid. Vanadic acid sublimated in like manner* affords, it is true, a blue $\ddot{H}\ddot{B}$ glass, but that is from continued O.P., and clear; this, after momentary H.P., and opaque.

(a) Mechanical mixtures with titanic acid are easily tested by $\ddot{H}\ddot{B}$ alone, as the former affords the characteristic pale blue fragments, blackened by H.P. I thus found that at least one-half of "pure" titanic acid, purchased by me in London, consisted of binoxide of tin.

(248). TUNGSTIDES, Tungstates.—Phosphoric acid is the proper detective reagent for this metal and its salts. That produces, with these added only to the extent of 4 per cent. in a bead on a platinum ring, when treated with H.P., a blue color so marvellously beautiful that it cannot be mistaken for any other, pyrologically obtained. The cobaltine borax blue has a violet tint; so has the blue of ultramarine. Alumina + cobalt oxide treated with O.P. possesses, it is true, a pure blue color, but is opaque; whereas the phosphotungstic glass is a perfect sapphire so far as color goes; nor do iron or manganese, combined with the tungstic acid, as in *Wolframite*, interfere, as they do when microcosmic salt

* Paragraph (245).

is used, with this azure hue, but seem rather to heighten it. The blue color produced by the digestion of zinc in the hydrochloric acid solution of tungstates is asserted by the chemists to be due to the partial reduction of those to "tungstous tungstate (WO_2, WO_3)"; and the treatment of the phosphoric acid with H.P. seems to have, in some cases, the effect of reducing basic oxides to lower oxides. I therefore believe that, in this case at any rate, tungsten acts as a base, and that the blue color is due to hydrated tungstic phosphate. I ground 1 per cent. of the mineral *Wolframite* into a paste with crystallized *Cassiterite* (previously ascertained to be free from tungstic acid), and obtained with the mixture in $\ddot{\text{H}}\ddot{\text{B}}$ quite an azure glass, so that much less color would have sufficed for detection of the WO_3 . Taking the percentage of tungstic acid and of tin in these ores respectively at 75, the amount of the former in the essay, here thus rapidly detected, was only .7 per cent.; and I am confident that, with the glass held over faint orange, as (*Dd*, Plate I.), I could have easily detected .1 per cent.

(a) A tin-white metal, apparently tungsten, is easily obtained by treating momentarily with a strong H.P., a glass composed of $\ddot{\text{H}}\ddot{\text{B}}$, in which tungstic acid has been dissolved to saturation by means of the cautious addition of potassic carbonate. It appears as a thick metallic coating over the surface next the H.P., and may be extracted by boiling the glass in a capsule, at the bottom of which the tungsten is found in tin-like spangles, which color an $\ddot{\text{H}}\ddot{\text{B}}$ glass blue. If the H.P. be continued, the coating disappears and is dissolved in the glass. If a weak H.P. be used, crystals appear in the glass, instead of the metallic coating.

Chemically-prepared "pure" tungstic acid procured in London gives in $\ddot{\text{H}}\ddot{\text{B}}$ two reactions: (a) blue-black insoluble amorphous masses; and (β) yellow creamy matter in large quantity. The former appears to be the proper reaction for WO_3 , and the latter, therefore, to be some impurity, probably of the lead class of oxides. In the description of the test for phosphoric with tungstic acid,* this London "tungstic acid" was used.

(b) When *Scheelite* is dissolved nearly to saturation in borax glass,† and the clear cold bead treated with a gas O.P., that at once becomes opaque, milk white. This reaction is described in Plattner's and other works; but what is *not* described is the curious fact that if the O.P. be pure and perfectly blue, by further application of it, *metallic tungsten* is produced, with a greyish or tin-white metallic lustre, as a film or coating to the bead.‡ Although thus easily produced, the metallic fragments seem infusible and indecomposable in the same bead in

* Paragraph (216, A).

† Mr. Warrington Smyth, in the 'Manual of Scientific Inquiry,' published by the Lords of the Admiralty, evidently confounds the German term "Borax glas" with fused boric acid (see Bristow's 'Glossary,' page xxi.).

‡ See also (a).

an after O.P., only glowing red hot long after the heat has been removed. Further addition of *Scheelite* (in fine powder) weakens or almost destroys this reaction; but quite large white crystals then form throughout the beads, as double-pointed pyramids, very similar to those of the mineral. In order to produce the metal, the first-mentioned point of saturation must be prepared, and the pure blue O.P. then applied to the *cold* bead. With these precautions, this extraordinary fact is quite easily ascertained to be a fact.

(249). STANNIDES, Stannates.—Tin *ores* (e.g. *Cassiterite* and *Stannite*) being so easily recognized by the immediate efflorescence of the binoxide under O.P.—a phenomenon exhibited by no others except those of zinc, from which these are readily distinguished*—can scarcely form a question here, even to the beginner, though it is interesting to find with what metallic elements the tin may be associated in the ore. This should be examined, therefore, as follows:—Paste of the crushed ore is plastered with a penknife above and below some pure (proof) lead in a keyhole mortar on aluminum plate, and the mass fused in O.P. until the mortar is burned away. The upper, or white part of the sublimate is then gently scraped off the aluminum with the penknife, and applied to a red hot $\ddot{\text{H}}\ddot{\text{B}}$ glass in O.P. Stannic acid apparently causes the glass to remain slightly opalescent on cooling, a pure plumbic-sublimate glass remaining clear. Stannic binoxide remains as insoluble white fragments, which may be further examined in the microscope, if desired, by clarifying the glass with a few specks of potassic carbonate. The glass, however, is better clarified by fusing with it an excess of fresh pure $\ddot{\text{H}}\ddot{\text{B}}$, by making a bead of it, in fact; for by this means plumbostannic oxides can be distinguished from the plumbosilicic and plumbocalcic sublimates, which also afford in $\ddot{\text{H}}\ddot{\text{B}}$ a glass slightly opalescent, with white insoluble fragments,† but are *not* clarified by the addition of further $\ddot{\text{H}}\ddot{\text{B}}$. The insoluble fragments are then to be dissolved, and no more, by the further cautious addition of potassic carbonate. The presence of titanio acid in this glass is proved, after the application to it of a short H.P.,‡ by opacity and blueness round the platinum wire. Tantalic and columbic acids are detected by applying a fragment of calcined lime to another similar glass, containing a little more $\ddot{\text{H}}\ddot{\text{B}}$, when a red-brown ball is formed.§ To detect tungstic acid, the sublimate is applied to an $\ddot{\text{H}}\ddot{\text{P}}$ glass, which, in that case, turns blue, but remains clear after H.P. on cooling; by this means .1 per cent. of tungstic acid can be detected in tin.||

(a) The two ores of tin, however poor the specimens may be, are recognized perhaps more easily than any known mineral by the snow-white efflorescence which comes out on a fragment treated with O.P. on aluminum plate. The

* Paragraph (250, c).

† Paragraph (227, f).

‡ Paragraph (247).

§ Paragraph (246).

|| Paragraph (248).

oxide (*Cassiterite*) further sweats minute balls of metallic tin when thus treated with one-third of the heat required to produce the metal with soda, &c. *Stannite* gives slight indications of the presence of antimony.*

(250). ZINCIDES.—Every student of metallurgy must have noticed the extraordinary resemblance, in some points, between the comparatively new metal aluminum and zinc. They are both a bluish-white color; fragments of either melt rapidly under O.P., but will not fuse to a ball; both have extremely small specific gravity; both are among the best conductors of heat; while the oxide of either glows infusible in a strong O.P., analogous to lime; both alloy most readily with copper, to form "yellow metal;" and finally, both oxides dehydrate cobalt solution, one turning it blue, the other green, under O.P., the seeming cause of which difference will be shortly explained.

The points of dissimilarity are:—Zinc is one of the most volatile metals, aluminum one of the most stable, under O.P. Zinc is rapidly attacked by acids; aluminum only essentially by hydrochloric. Nevertheless, zinc, in a plate $\frac{1}{16}$ inch thick, resists to some extent the heat of the pyrogene; and small fragments of arsenic, antimony, silver, bismuth, gold, &c., may then be fused upon it with impunity, as on aluminum. Copper, however, attacks it at a white heat, but does not attack the latter metal, because it cannot be raised to white heat upon that.

(a) Zinc is stated in chemical works to have only one oxide, which is white, but yellow hot. Zinc oxide, however, as can be seemingly proved by oxidizing the pure metal on aluminum plate with a strong O.P., is in reality orange; incompletely heated, or mixed with a proportion of the white sublimate, which reduces the chromatic tone, it appears yellow. The white sublimate seems to be the hydrate of zinc, formed by the extreme attraction the oxide, separated by heat, evidently has for atmospheric water, as is proved by it dehydrating cobalt solution; and the green color then formed under O.P. is apparently due to the chromatic combination of the cobalt anhydrous blue, and the zinc hydrous yellow. Charcoal as a support for zinc heated in O.P. seems to supply this water to the anhydrous (orange) oxide, which then becomes white on cooling; but on burnished aluminum plate there can be no such supply, and the heat, moreover, is nearly as great at the part where the sublimate is deposited as round the essay itself, while on charcoal, the part immediately beyond the red hot proximity of the essay, is comparatively cold. Hydrated substances generally seem to assume their anhydrous color while hot, and their hydrous one on cooling; thus cobalt hydrates are blue hot, and pink cold; chromic sesquioxide, red while hot, and green cold; copper oxide, green hot, and blue cold, &c. During the late fire at the Woolwich Military Academy,† I observed a zinc-roofed tower covered with

* Paragraph (237).

† February, 1873.

yellow oxide half way down, and it remained yellow for a week. I attributed the fact, at the time, to some adulteration of lead; but as lead is dearer than zinc, the conclusion was unsatisfactory. The treatment of zinc on aluminum, however, soon shows us the reason. The intense and continued heat, with red-hot bricks supporting it, had partially dehydrated the zinc hydrated oxide, which was therefore yellow. When perfectly dehydrated, it becomes orange; and still further heated (on aluminum), it turns black.

(b) The black sublimate (suboxide?) of zinc is easily made by treating a fragment of pure zinc with a momentary O.P. on aluminum plate, collecting the sublimate thus formed round the essay by gently scraping it off with a penknife, and repeating the process. O.P. must not be continued, because the black part becomes covered with the white oxide, and is perhaps itself converted into it. The black thus obtained is of a very fine description, like velvet, and would probably answer as a pigment. The orange oxide certainly would.

(c) Although one of the most volatile of metals *per se*, zinc in combination (especially with silica, as in *Calamine*) stands by its associates (as iron and manganese in *Franklinite*) with great pertinacity, under the strongest O.P., and the compound, even when powdered, often affords only an indistinct sublimate. It is, thus treated, not easy to determine with certainty the presence of a small quantity of zinc in a mineral, without referring a fragment to a glass of H₂ for identification; but instead of commencing thus violently, if the fragment the size of a pea be placed in the platinum decrepitating apparatus,* and gently heated, zinc shows itself immediately, if the mineral has a dark color, in the shape of a very pretty bluish-white efflorescence like thin hoar frost, over the surface next the platinum.† This reaction is an infallible detective of the smallest trace of zinc, and shows that metal to be present in most *Galenas*, in *Bournonite*, *Boulangerite*, *Spaniolite*, &c.; for no other metal with the exception of tin affords it. Obtaining the reaction from *Spaniolite*, and thinking it to be caused by mercury, I tried the process with *Cinnabar*, and, by a curious coincidence, in the first fragment tried obtained it, and therefore for some time considered mercury to be the cause; but eventually ten other fragments of cinnabar giving no such reaction, I found it to be due to zinc. The efflorescence is distinguished from that afforded by tin in two ways: (a) the former is yellow hot; and (β) the latter is steadfast under O.P., the former is not.

* Paragraph (160).

† Sometimes where there is much iron present, and especially some in the state of protoxide (as in *Franklinite*), the zinc oxide is apparently reduced, and then appears like a thin coating of pale brass next the heat. In this case it cannot be volatilized, but is easily recognized as zinc by this peculiar appearance, which is not given, within my knowledge, by any other oxide.

(d) Zinc is instantly detected in *Calamine* by heating the powdered mineral (or a fragment when decrepitation is cured), which turns bright yellow, returning to white on cooling. There seems no necessity for the application of cobalt solution in such cases.

(e) The sublimate of zinc is detected in the white one of lead on aluminum plate by treatment with P.P., when, if the former is present, an orange color is assumed. In H.P. this turns black, which can be made brownish-orange again by P.P. In the case of its combination with white antimonial sublimate, P.P. produces a bright orange while hot, which fades to lemon yellow on cooling. When black is produced by H.P., it is not so easily changed as in the case of lead, and the outer fringe or halo (which seems to consist of antimonious oxide alone), when blackened cannot be changed at all. Finally, the antimonious sublimate boiled in water is strongly acid; the zinc sublimate nearly neutral. These reactions are the more valuable, inasmuch as, according to Plattner, the cobalt solution test is here of no use. "When the substance contains little or no zinc, but much antimony, a combination of cobalt with one of the acids of antimony will be formed, which likewise has a green color, and cannot be driven off with the O.F. In this case zinc can only be found with difficulty."* But the test (241, *note*) obviates the necessity for any of these, and is perhaps the most delicate and rapid one for zinc. But if any doubt arises in the mind of the operator as to the presence of a trifling quantity of zinc in the essay, the following process seems calculated to altogether remove it, and, indeed, to be decisive. Fuse the crushed essay with pure lead (*probir blei*), on a keyhole mortar over aluminum plate in O.P.; a little of the upper, or white-border part of the resulting sublimate is then tested in $\text{H}\ddot{\text{B}}$, where, if any zinc oxide is present, it appears as a cotton-woolly, white mass, which cannot be mistaken. In this manner it is easily detected in the Johannegeorgenstadt *Uraninite*. Pure zinc sublimated with lead, as above described, affords in $\text{H}\ddot{\text{B}}$ clear balls, and so indeed does *Uraninite*, though in that some of them take up molybdic acid,† and become green in consequence; the latter I at first ascribed to lime, but afterwards ascertained that the plumbocalcic sublimate does not afford balls.‡

(f) Zinc in considerable quantity in a mineral or alloy evolves, when pyrogenically heated, a smoke which takes fire from the O.P. (the metal itself does not ignite), and burns with a momentary, but very beautiful pale blue pyrochrome. The green phosphorescent light with which the oxide, in any quantity, shines in O.P. is also a very characteristic indication of this metal.

(g) Phosphoric acid is a very delicate detective of ZnO , used by applying a

* Page 326.

† Paragraph (235, c).

‡ Paragraph (227, f).

speck of the mineral, as, e.g. *Franklinite*, to a hot bead of the former and treating with a momentary O.P., when ZnO is betrayed by a cotton-woolly precipitate like nothing else.

(251). ALUMINA AND THE EARTHS PROPER.—Although a rapid way of distinguishing Alumina (which may be taken as the type of this series) is given farther on,* the methodical way of analyzing these pyrologically is first to separate the silica—for they are almost invariably found as silicates—by boiling in water acidulated with boric acid, as above directed. A little (a few specks) of the desiccated residue is then taken on an H₂B glass, and if, as is generally the case, no definitely distinctive reaction thus takes place, a pin's-head fragment of pure lime is added, as nearly as possible over the specks, and the glass is heated and turned over and over in O.P. until those are dissolved. Zirconia is almost the only one of these earths which will not thus dissolve: it remains for the most part outside the ball as a white suffusion, and can be thus recognized and separated (by boiling water). It is, indeed, more like silica than alumina, as will be seen under its head.† The whole of these rare (except alumina) earths can now be recognized by the reactions given under their separate heads. If metallic oxides are present, they will give the ball their usual colors, without interfering with the tellurine reactions, except in the case of cobalt, which would spoil the erbian or yttrian reaction, but the three are never, within my knowledge, found together. Iron oxide in considerable quantity spoils the colored yttrian reaction, and I have not yet the means of separating the former, pyrologically, without injuring the latter, but this mode of manipulating these oxides is not yet half developed.

(252). ALUMINIDES, Aluminates.—Aluminum is placed here for the reason given in Paragraph (250). It seems to form the link between the volatilizable metals and those following. The presence of alumina in minerals is concealed chiefly by three things: (α) the simultaneous occurrence of two-thirds silica in the mineral; (β) the presence of metallic oxides; and (γ) phosphoric acid. The first two combinations prevent, or at least seriously interfere with, the action of the cobalt-solution test, which forms a pale indistinct blue in the third case, but still sufficient to recognize alumina as in *Wavellite*. As a means of enabling the student to recognize alumina under such conditions, the following superficial examinations are given here. They were taken at random from the boxes of a Freiberg cabinet, numbered, as below, at the top of each box.

(1) *A white, compact Mineral*.—A fragment heated in O.P. on aluminum plate gently, gave a violet pyrochrome, so applied H.P., which made this reaction (potash) much stronger. A drop of water on the hot fragment caused a black

* Paragraph (252).

† Paragraph (254).

stain on the plate, which reaction a slight rotten-egg smell in the steam showed to be due to sulphur. A few specks of the powder of this fragment effervesced strongly on being heated in an $\text{H}\beta$ glass with O.P., showing that the mineral is a sulphate. Nothing but fat-like fragments with a little opaline matter (free water) resulted from the final decomposition of the powder in $\text{H}\beta$. The essay was apparently, therefore, aluminic sulphate, with potash, and cobalt solution confirmed the presence of alumina.

(2) *A crystalline, semitransparent, white Mineral.*—A fragment in O.P. on aluminum plate glowed = iii. (p. 213), with an orange pyrochrome, and fused on the edge. (Presence of an alkali or lime with silica.)* After H.P. and a drop of water, left no stain on the plate. After cobalt solution O.P. fused the edge to a blue glass. (Presence of an alkali with silica.) A speck or two of the powdered essay gave in $\text{H}\beta$ under O.P. an icy mass, which again indicated an alkali with silica, as the latter alone would have had sharp angular edges. The glass, therefore, vesiculated, breathed on, and approached to a lighted spirit lamp, gave a strong reaction for potash,† while the green pyrochrome of the $\text{H}\beta$ being slightly yellowed, *also* indicated a little soda. So far, only silica, potash, and soda had been obtained; but as the mineral could not be a *potassic* silicate, search was made for another base, which manganese solution, heated in O.P. on a fragment, indicated to be alumina from the brown spots.‡ To confirm this surmise, a fragment of the mineral crushed by the (α) forceps, ground between agates with water and some crystallized $\text{H}\beta$ and boiled, gave, besides a quantity of undissolved silica, and a gelatinous or starchy solution of dissolved silica, a mud-colored sediment, which, washed with fresh boiling water, dried, and treated again with water, gave the peculiar unmistakable smell of wet alumina, and some of it in an $\text{H}\beta$ glass gave fat-like fragments of pure alumina. I *guessed* this mineral roughly (the whole operation only took ten minutes) to contain about 70 per cent. silica, 10 per cent. potash, 2 per cent. soda, and 15 per cent. alumina.

(7) *A white, compact, opaque, sugary Mineral.*—On aluminum plate fused on edge, gave a blue glass with cobalt solution in O.P. like the last, but an orange pyrochrome so strong that it seemed to run up the blue pyrocone (soda). In an $\text{H}\beta$ glass an icy transparent mass, with, also, some white waxy balls (lime and alumina); vesiculated, a slight potash reaction. Green pyrochrome of $\text{H}\beta$ completely orange (soda). I guessed this to contain 60 per cent. silica, 15 per cent. alumina, 5 per cent. lime, 10 per cent. soda, and 2 per cent. potash.

(12) *A white, semitransparent, vitreous Mineral.*—On aluminum plate in

* Silica *per se* is infusible before the pyrocone: if, therefore, an obviously *quartz* mineral fuses, there must be, combined with the silica, either an alkali or alkaline earth, and such fusible compounds of course form, under heat, blue glass with cobalt oxide.

† Paragraph (129, *r*).

‡ Paragraph (113, *a*).

O.P. a red-violet pyrochrome (lithia), fused on edge, and a blue glass with cobalt solution. No black stain in H.P. and water. In $\ddot{H}\ddot{B}$ an icy mass and white fat-like fragments: no balls. Green pyrochrome unchanged; vesiculated, a strong potash reaction. I guessed it to contain 65 per cent. silica, 20 per cent. alumina, 5 per cent. lithia, 5 per cent. potash. The whole essay took about ten minutes.

(16) *Yellowish-white, vitreous or waxy Mineral*.—On aluminum plate in O.P. glowed about ii. (p. 213), and became yellow-green; of course, this reaction showed what the mineral was, and that there was no use looking for alumina in it. The complete essay of it, therefore, is not given here.

(6) *A rusty white, quartzly Mineral*.—On aluminum plate in O.P. glowed =iii. (p. 213), with a strong orange pyrochrome; with cobalt solution, blue in parts, remainder black. In $\ddot{H}\ddot{B}$ an icy mass, no fragments; but on treating as in (2) fat-like aluminous fragments were obtained in $\ddot{H}\ddot{B}$. Pyrochrome orange; vesiculated, gave a slight potash reaction. Guess of contents, 60 per cent. silica, 15 per cent. soda, 16 per cent. alumina, 2 per cent. potash.

(1) Was *Aluminite*, containing, according to an average of the analyses given in Dana,* sulphuric acid, 39.42; alumina, 37.95; water 11.97; potash, 10.66. (2) *Adularia*, containing silica, 65.69; alumina, 17.97; lime, 1.34; † soda, 1.01; potash, 13.99. (7) *Analcime*, containing silica, 56.22; alumina, 22.22; lime, 5.8; soda, 7.4; water, 8. (12) *Petalite*, containing silica, 74.1; alumina, 17.41; lithia, 5.16; lime, 0.32; ign. 2.17 (Gmelin). (16) *Baryto-calcite*. (6) *Albite*, containing silica, 68.46; alumina, 19.30; lime, 0.28; soda, 11.27; potash, 0.65 (G. Rose).

(a) Another good and even more rapid way of proceeding is to treat a few specks of the powdered mineral at once in an $\ddot{H}\ddot{B}$ bead, along with a small pin's-head fragment of caustic lime in O.P., when the silica is decomposed, and part becomes soluble, giving rise to opaline matter in the bead, while the alumina combines with part of the lime, to form white opaque *waxy* balls, which are extremely characteristic, as the silicious lime balls are either *sugary*, opaque white, or semitransparent with grammatic crystals.‡ Chemically prepared alumina (which effervesces at first in $\ddot{H}\ddot{B}$, through the retention of a little of its ammoniacal precipitant) when treated thus with lime in $\ddot{H}\ddot{B}$, does not form waxy opaque, but clear balls, which, however, extracted by boiling water and added to a fresh $\ddot{H}\ddot{B}$ bead under O.P., evolve a number of small bubbles, and a quantity of white (not opaline) streaky matter into the bead, which becomes nearly opaque in consequence. It is thus quite evident that a combination of the anhydrous calcic borate with the otherwise insoluble alumina has taken place, and that the combined alumina is displaced by fresh $\ddot{H}\ddot{B}$ and more heat. The glass still

* 'System of Mineralogy,' 1868.

† There was no lime in my sample.

‡ Paragraph (218, 4).

remains clear (with the exception of the bubbles above mentioned) even in P.P., and this fact forms an excellent way of distinguishing alumina from glucina.* A very pure hydrous aluminic silicate, such as *Meerschalmunit* (a mineral discovered by me at Simla, in the Himalaya, and called so from its extraordinary resemblance, not merely in appearance, but in commercial qualifications, to *Meerschäum*), gives in H₂B with lime a clear ball with bubbles, which becomes semiopaque and sugary on being added to a fresh H₂B bead.

(b) For the separation of alumina from phosphoric acid, *vide* Para. (216, c).

(c) A small piece of aluminum foil heated in a strong O.P. on aluminum plate gives no sublimate, but gradually burns away with an orange pyrochrome, becoming first a dull dark blue, like a piece of slate, and crumbling by the slightest squeeze, and finally a white powder which becomes blue by heating with cobalt solution in O.P.; yet Henry Rose says of it:† “Quand on la chauffe à l'air jusqu'au rouge, il prend feu, brûle avec un grand éclat, et se convertit en aluminie”! This shows what we owe to St. Claire Deville who produced the metal, as we now possess it, in 1854.

(d) One of the most beautiful substances and brilliant colors in nature is essentially nothing but a kind of clay, or aluminic silicate! In *Lapis lazuli*, as in the *Sapphire*, there is nothing in our feeble appreciation of creative resources to account for the most pure, the most heavenly blue color in mineral creation; but silica, which is white; alumina, which is white; a mere trace of soda, which is white; and a mere trace of sulphur, which is yellow! To what, then, is the lovely azure hue of this mineral to be attributed? It vanishes when dissolved in the purest flux, much as the “blue vault of heaven” does when a cloud passes over it. It turns a dirty green when treated with O.P. in fine powder alone.‡ Are we to suppose, not merely as we have good reason for supposing, that the most beautiful color merely exists as modified rays of light, but that these modifications can only be instituted in such rays by material substances *in a certain condition*? that the state of normally colorless or white substances can be so altered, or those combined, by the Almighty will, as to produce the most seraphic blue color it is possible to conceive, but which, touched only by the chemist, vanishes like the colors of a prism when that is turned beyond the refracting angle? We cannot doubt the fact, and the fact certainly seems to indicate that the power of producing all these chromatic modifications of white light is possessed by a few, a very few, elements only; and that the many “colored” oxides known to us are merely altered conditions of those elements.

* Paragraph (253, a).

† French translation, by Peligot, 1843.

‡ Liebig erroneously states (p. 127, ‘Familiar Letters on Chemistry’), that “*Lapis lazuli* remains unchanged by exposure to air or to fire.”

(e) Although artificial *Ultramarine*—the present mode of preparing which was discovered by Gmelin—is deservedly esteemed as a pigment little inferior to the real one, still it is inferior, as artists well know, and, moreover, fraudulent imitations are sometimes made with smalt, &c., so that the following illustrative examples may be found useful. An artist, who had several blue (“*Ultramarine*”) pigments lying by for twenty years, until he had forgotten what they were, sent me four powders in packets, marked 1, 2, 3, 4. I began with No. 2, which seemed a deeper toned blue than the others. My first object was, of course, to see if the powder contained cobalt, in which case there would have been no necessity to proceed further, so a few specks of the powder were taken on a hot $\ddot{\text{H}}\ddot{\text{B}}$ glass, and treated with O.P. They effervesced, and at the same time emitted a slight smell of HS, so that there was contained in the powder certainly a sulphide, and probably a sulphate. The blue color then vanished, and a silicious semitransparent mass remained, which was evidently either silica or a silicate with a few minute, round, transparent, yellow superficial globules, which there was little danger in attributing to sulphur. Continued O.P. slightly decomposed the silicious mass, among which were then detected, with a lens, small, white, fat-like fragments of alumina. It was evident, therefore, from this one operation, that this was either natural *Ultramarine* or artificial (neither of which I had before examined), though there still remained to be proved, by the treatment of some of it in $\ddot{\text{H}}\ddot{\text{B}}$, whether it contained soda, by the yellowing of the green pyrochrome; and, by vesiculation, whether it also contained potash; both of which questions this reagent answered in the affirmative.

The next powder tried was No. 4, first in $\ddot{\text{H}}\ddot{\text{B}}$ under O.P., when some of the unabsorbed powder turned a dirty green, and, besides the silicious mass, a little brown organic matter momentarily appeared; also indications (a faint streak) of free phosphoric acid, which (2) did not give. With *Epsomite*, potash, and fresh $\ddot{\text{H}}\ddot{\text{B}}$, this glass gave the reaction of a considerable quantity of phosphoric acid.* In an $\ddot{\text{H}}\ddot{\text{P}}$ glass, a moment's heating of fresh powder brought out a pungent smell, which showed more sulphur than (2). No alumina could be thus separated in this specimen, the silicate being too perfect. The other reactions were similar to those of (2). No. (1) behaved like (2), but showed a little lime in $\ddot{\text{H}}\ddot{\text{B}}$. No. (3) gave at once a reaction in $\ddot{\text{H}}\ddot{\text{B}}$ for cobalt + an alkali and silica; and the alkali was *not* soda. It was evident from the organic matter and the presence of phosphoric acid, which could not have been put into an imitation, as they were not known to exist in the original, that No. (4) was natural *Lapis lazuli*; that Nos. (1) and (2) were good imitations, or artificial *Ultramarine*, and that No. (3) was either a cobaltine fraud, or common smalt. I stopped the

* Paragraph (216, c).

examination of it when I found it contained cobalt, but there was evidently considerable alkali present. Nos. (1) and (2) gave no indication of phosphoric acid.*

(f) An excellent way of distinguishing between alumina and silica is to fuse the essay with pure lead,† and treat some of the resulting sublimate in $\text{H}\ddot{\text{B}}$ under O.P. In both glasses insoluble fragments of silicate and aluminate of lead respectively are found; but the silicious glass is opalescent on cooling; the aluminous glass is clear.

(253). GLUCINIDES.

As it is apparently impossible to procure any of these rare "earths" here, in a pure state, I copy the description of their pyrological behaviour given by Berzelius, from which that of Plattner and other writers is evidently taken. "Glucina, alone, remains unchanged. It is dissolved in large quantity by borax and the salt of phosphorus, into a transparent glass which is rendered opaque by flaming. If a larger quantity be added, it becomes on cooling milk white. It is not attacked by soda. With cobalt solution gives a grey or dark grey mass."‡ If anyone can detect Glucina in a mineral from this, he must be gifted with superhuman acuteness. I treated German *Beryl* (which has much the appearance of greenish quartz) as follows, without much more success. A fragment, crushed with the (α) forceps, ground with crystallized $\text{H}\ddot{\text{B}}$ and water to a paste between agates, and boiled; the solution gave the reaction in an $\text{H}\ddot{\text{B}}$ glass of soluble silica.§ There were two residues, one lighter and darker|| than the other; which were in a great measure separated by slanting the capsule (Fig. 35) in which they were boiled, while nearly full of a third washing of water, downwards at an angle of about 3° or 4° , gently tapping it the while with the hilt of the pliers; this, of course, brought the layer of light powder (α) in front of the heavy powder (β). Retaining the capsule in this position, I drew off the water, first with my little finger, from the edge of the slanted dish, then with a strip of bibulous paper.¶ Still retaining the position of the capsule, I dried it thoroughly underneath with a lighted spirit lamp, and then scraped away which powder I wished with a penknife; (α) gave in an $\text{H}\ddot{\text{B}}$ glass under O.P. peculiar *feathery* fragments, white, opaque, and insoluble, but easily dis-

* I have been informed, since this analysis was made, by the artist who sent me these specimens, that, after reading my report, he remembered the powder marked "4" was very expensive indeed (about 4l. 10s. an ounce), and he stated that the best artificial ultramarine has been proved by many trials, although apparently when freshly applied, as beautiful blue as the mineral or *Lapis lazuli* pigment, to be not so durable as that.

† Paragraph (218).

‡ Page 53, American translation.

§ Paragraph (218).

|| What is meant is, that it was lighter in weight and darker in color than the other.

¶ Paragraph (129, f).

tinguishable from the rounded, fat-like masses of alumina, which were those afforded by (*B*); (*a*) may have been pure Glucina, but I doubt it.

(*a*) Glucina is best detected in *Beryl* by boiling its paste in water with $\text{H}\ddot{\text{B}}$, decanting the solution, which withdraws the silica, and treating the evaporated powder in $\text{H}\ddot{\text{B}}$ with a fragment of lime. Alumina is evolved as white streaky matter, and the remaining ball is clear under strong O.P., but on cooling, semiopaque, white, and highly crystalline. As this semiopaque ball is something, but not very, like the ball at first produced in $\text{H}\ddot{\text{B}}$ by calcic silicate, it might be mistaken for that. The distinction is easily made by extracting the ball with boiling water, and treating it in a fresh $\text{H}\ddot{\text{B}}$ bead with a strong O.P., when the silicious lime ball diffuses part of its silica over the bead as in a soluble, opaline state; the glucinic lime ball, on the contrary, remains unaltered.

(254). YTTRIDES.

No reactions of Yttria are given by Berzelius, as he says,* that what he considered yttria had been found by Mosander to consist of erbia and terbia besides that; yet the atomic weight of yttrium is 62, and that of erbium 112! Wöhler appears to have produced a metallic powder from yttria, very like what he obtained from alumina, and, like that, taking fire when heated to redness in air.† Plattner gives‡ the "wet" method used by Mosander in separating these earths. Yttria procured by Professor Stokes from Görlitz, in Prussia, does not effervesce or form balls in $\text{H}\ddot{\text{B}}$, but separates into white stearic masses like those of alumina, only distinguishable from that by curd-like or flocculent matter which clings round them, and seems to be chemical water, for it can be proved not to be phosphoric acid by the addition of potash and $\text{H}\ddot{\text{B}}$.§ This bead vesiculated gave a strong potash reaction, also, I believe, shown by the spectroscope, and probably due to the precipitant in the preparation of the earth. A ball of lime borate heated under O.P. in this bead rapidly dissolved the yttric fragments, forming, when saturated with more in fresh $\text{H}\ddot{\text{B}}$, a clear but very crystalline ball with a pinkish tinge.|| The tinge, however, appears to be due to the presence of erbia, as the ball gives a faint but distinct and almost complete erbic spectrum. (See Table VI.)

(*a*) *Gadolinite* (from Kårarfvet), on the contrary, freed from the greater part of the silica by boiling the green powdered mineral with $\text{H}\ddot{\text{B}}$ ¶ forms bright green opaque balls in $\text{H}\ddot{\text{B}}$ with the above-mentioned flocculent matter round them. *Orthite* or *Allanite* gives these green balls, and also the red-brown ones of the ceric oxides; a reaction explained by a reference to the analyses

* Page 53.

† Paragraph (253, c).

‡ Page 234.

§ Paragraph (216, c).

|| Distinct from Erbia, Paragraph (255).

¶ Paragraph (218, g).

cited of these minerals in Dana's 'Mineralogy,' an average of which gives about three times as much cerium to the latter as to the former. The ball formation in $\text{H}\ddot{\text{B}}$ seems due to lanthana and lime, as neither yttria nor ceria alone forms balls. The brilliant green color of the ball, almost equal to that of a copper salt, is probably caused by protoxide of iron (of which there is about 15 per cent.) and lime, the combination of which affords green balls in $\text{H}\ddot{\text{B}}$,* heightened perhaps by ceria, which can change the strawberry tint of the didymium borate ball to a red-brown.

(b) The pyrological analysis of these earths has yet to be developed, until when the green opaque balls in $\text{H}\ddot{\text{B}}$ are extremely characteristic of yttric combinations, and the indication may be confirmed by their peculiar behaviour in $\text{H}\ddot{\text{P}}$, in which they immediately become white with coralline or dendritic crystallizations. When all is dissolved, the bead is red-brown hot (iron); pea green cool (?); faint pinkish and very crystalline cold (didymic oxide).

(255). ERBIDES.—Plattner gives no separate mention of Erbium, describing it† with terbium (the existence of which is now denied by chemists) under the general head of "Yttererdehaltigen Mineralien." Neither Berzelius (1845) nor H. Rose‡ mention it at all, though discovered by Mosander in 1840. A small quantity of the chemically separated earth, courteously given to me by Professor Maskelyne, has a sandstone dust appearance, which, when some of the powder is heated on aluminum in a long P.P., becomes yellow. In a candle H.P. it carbonizes like alumina. In $\text{H}\ddot{\text{B}}$ a small pin's-head speck effervesces, and then floats in amorphous, but very small fragments, which are white, opaque, stearic looking, like those of alumina, and seemingly quite infusible, even under a high-angle O.P. This is peculiar behaviour, as the fragment alone in a strong O.P. glows like lime, or = i. (p. 213), and effervesces in combining: these phenomena being highly characteristic of ball-forming oxides in $\text{H}\ddot{\text{B}}$. As this kind of analysis seemed to stop here, I tried a synthetical process, to see if I could, by adding lime and the other oxides contained in *Gadolinite*, separately, obtain something like the green opaque ball afforded by that mineral (254, a); a small pin's-head speck of lime, therefore, was used to obtain a lime-borate ball, to which (in a fresh $\text{H}\ddot{\text{B}}$ glass, in order to eliminate the chemical water) as much of this erbic oxide was added as *could* be dissolved in the ball, not the glass, under a strong O.P. The erbium *then* gave off a quantity of opaline matter, which was proved to be water.§ When thus saturated with erbium, the ball extracted by boiling water was—the only case I know of—not spherical, but flat, shaped like a double convex lens (which might, however, be due to its having been made in a glass, not a

* Paragraph (260, d).

† French translation, 1843.

‡ Page 234.

§ Paragraph (216, a).

bead), and a beautiful bluish-violet color = (Gδ), not unlike, but redder than the bluish ball apparently formed by lanthana;* but that earth is at once distinguished from this, by the fact that the former forms balls in H₂, while the latter, as above described, does not. This is quite an unexpected reaction for erbia, and therefore most interesting; and not less so the spectrum afforded by this ball, in the spectrum lorgnette, as follows.

(α) Erbia glows = lime under a very moderate O.P., which is probably the cause of its affording a continuous pyrospectrum. The calciborerbic ball, above described, affords, when spectroscopically examined, a very distinct "absorption band" in "the green" of the solar spectrum, to the left of "Eb," like one of the lines of didymia, but proved to be not due to that earth, by the fact that its thick line near "D" is totally absent. As the rather thick line to the left (or red side) of the solar band (Eb) seemed at first to consist of two or more thin lines, which became one and thick when the erbic solution was stronger, I hoped, by dissolving erbia in this very limited space to saturation, to obtain fresh lines in the spectrum. To do this it was necessary to add more lime, and the first result of this was to remove the pretty color of the ball, which was now only a faint pink, although a considerable quantity of fresh erbia had been with difficulty dissolved in it. But, on the other hand, my anticipations were realized, for in the spectrum two faint but distinct lines now appeared to the right (or green side) of D, having the appearance of one thick line, which seems, in the small field obtainable with a spectrum lorgnette, to be identical in position with that band of didymia. Dissolving still more erbia in this glass by means of fresh lime, I obtained another line "in the red," apparently to the left of that of lithia, and the spectrum afforded was as follows. (1) Several lines (having the appearance of one thick black line), quite filling up the space between Eb and E. (2) A brownish but very distinct and thick line on the right of D. (3) An indistinct but black line close to the red end of the spectrum. It now remained to be seen if an extremely weak solution of didymia in a similar flux would afford anything like these lines, and this was effected by taking up a speck of didymia and dissolving it under O.P. in a calciboric ball, which certainly showed the thick lines to the right of D, but only one line in the green, just to the right of E.†

(256). ZIRCONIDES.—Berzelius says of Zirconides:‡ "Alone, as prepared by the ignition of the sulphate of zirconia, it emits a more brilliant light than any other substance; the whole room is illuminated, and so great is the power of the light that the eye can scarcely endure it, even by daylight. Its behaviour with borax, soda, and salt of phosphorus, is like that of glucina, with

* Paragraph (229, b).

† Vide Paragraph (229, d).

‡ Page 53.

this difference, that it is more slowly dissolved by the latter, and sooner gives an opaque bead." Treated like *Beryl*,* *Zircon* yields a copious residue of a greyish color, but giving no aluminous smell when watered. This residue strongly heated in O.P. certainly glowed intensely (much more than a fragment of the mineral), but not so much as lime; on moistening it, however, with a drop of sulphuric acid, the glowing was much more brilliant, and as no decomposition took place, it may be reasonably doubted if it is not the sulphate of zirconium which glows so intensely in O.P. It was scarcely attacked by a bead of $\ddot{H}\ddot{P}$, but on adding soda, solution of about half took place, the other moiety clinging, insoluble, to the platinum wire. The bead was yellow hot (iron), and a faint bluish tint cold. As silica is said to be nearly insoluble in sodium pyrophosphate, the clear part of this bead ought, according to the usual chemical theory, to have chiefly consisted of phosphate of zirconium. A speck of the crushed bead gave, in a glass of $\ddot{H}\ddot{B}$, an icy mass, quite different from the reaction of silica dissolved in $\ddot{H}\ddot{P}$.† A few small crystals of *Epsomite* added to this glass caused the whole to become opaque, white, with some clear balls of (apparently) magnesian borate. Adding now, by degrees, traces of potassic carbonate, a clear glass was obtained, in which the slightest addition of the original zirconium phosphate gave the beautiful opaline reaction of phosphoric acid‡ very well.

(a) Red zircons must be selected according to the plan recommended by Berzelius.§ "Anyone who wishes to prepare zirconia from the Ceylon mineral will do well to ignite the *Zircons* and *Hyacinths*, and then select the colorless grains, since those which do not lose their color are *Spinel*, *Essonite*, or *Pyrope*." Proceeding thus, I found that at least half of the red crystals in the specimens of zircons got at Freiberg were not zircons.

(b) Crystals which lose their color in O.P., crushed to a paste with the (a) forceps, and then between agates with water and $\ddot{H}\ddot{B}$, produced on being boiled the usual starchy solution of soluble silica, and a greyish-white residue. This latter behaved much like insoluble silica in $\ddot{H}\ddot{B}$, being decomposed by a lime ball in the bead to a white suffusion; only that was not soluble in a fresh $\ddot{H}\ddot{B}$ glass like the silicious suffusion, and the ball had no grammatic crystals on its surface, remaining perfectly clear with the exception of a few bubbles. This ball showed, however, that it had dissolved some zirconia, by its giving in a fresh $\ddot{H}\ddot{B}$ bead a white suffusion copiously.

(c) Thus prepared, zirconia is absolutely insoluble in phosphoric acid, and a large addition of potash does not render it less so. Altogether, it seems in pyrognostic properties extremely like silica.

* Paragraph (253, a). † Paragraph (218, d). ‡ Paragraph (216, c). § Page 131, note.

(257). CARBIDES, CARBONATES.

Experimentation with pure Carbon is rather expensive work, as, in order to obtain reliable results, it is necessary to use diamonds; but even this does not, in England, necessarily imply extravagance on the part of the operator, as on merely mentioning my wish to make some experiments in this direction to Mr. Hunt, of the firm Hunt and Roskell, in Bond Street, that gentleman, although a perfect stranger to me, held out a positive handful of small diamonds as *vilia corpora* for me to operate on! I had, before this, found a small diamond, given to me by Mr. Slocombe, the jeweller, of Moorgate Street, as such, to dissolve completely and quietly in $\ddot{\text{H}}\ddot{\text{P}}$, with the application of a comparatively small degree of heat; and selecting a couple from those Mr. Hunt so liberally offered me, I found one, an artificially cut crystal, dissolve rapidly in $\ddot{\text{H}}\ddot{\text{P}}$ under O.P., while the other, a natural crystal, resisted the strongest heat in the same flux, although the edges of its facet were completely smoothed, and the whole crystal turned semiopaque. These curious results could not have been due to the gradual burning of the diamonds into carbonic "anhydride," because (a) each crystal seemed to melt rapidly away in the flux with the application of comparatively little heat; and (b) the bead of $\ddot{\text{H}}\ddot{\text{P}}$ in which they had been dissolved became extremely and abnormally deliquescent, and after remaining in a semifluid state in a bottle for about a month, gave out, on being reheated, a smell of burning fat: both of which phenomena also occur, though in a much less marked degree, to an $\ddot{\text{H}}\ddot{\text{P}}$ bead in which *gold* has been dissolved.

(a) Carbonates are readily recognized by the effervescence they cause either in $\ddot{\text{H}}\ddot{\text{P}}$ or $\ddot{\text{H}}\ddot{\text{B}}$, when heated there in O.P. This reaction is, it is true, also given by some sulphates, from which carbonates are, however, easily distinguished, (a) by not affording a smell of HS on treatment with water after a candle H.P., and (b) by their temporarily yellowing the $\ddot{\text{H}}\ddot{\text{B}}$ pyrochrome, while sulphates increase its greenness.

(258). CUPRIDES.

The presence of no metal is more rapidly, certainly, and minutely determined pyrologically in compounds than Copper. The test for it, to be described, is indeed so delicate as to become troublesome, on account of the difficulty of getting rid of the cupric reaction afterwards from the platinum wire. It is based on the reciprocal property apparently possessed by $\ddot{\text{H}}\ddot{\text{B}}$ and copper, that of oxidizing this, or reducing its oxide, immediately on application, to the state of suboxide, which then instantaneously and copiously emits its well-known blue-green pyrochrome; this, of heightening, or rather changing, the yellow-green pyrochrome of that. The effect is more striking when a candle is used, as the sulphur in coal-gas lessens it. I at first thought that the combination

of the two pyrochromes produced a third, brighter and different from either, as in the case of cupric chloride; but by comparing it with the pyrochrome of a fragment of pure *Cuprite* placed in the same line of fire (or O.P.), I found the two pyrochromes identical, the idea of superior brightness and more vivid greenness being apparently caused by an optical deception. The retina, accustomed to receive the duller yellow-green rays of $\text{H}\beta$, is deceived by the suddenness of the change, the yellow rays being, apparently, entirely absorbed.* It must be admitted that this is by far the most delicate reaction known for copper, of which it betrays the presence of a trace far too minute to see or identify in any other manner; the present method of obtaining the suboxide in a bead of microcosmic salt, by reduction with tin on charcoal, being comparatively coarse, and much more tedious; besides which, the latter process utterly fails in presence of bismuth or antimony, as admitted by Plattner.† Whatever be the cause, the effect of this reaction is so perfect, that I have, by means of it, satisfactorily proved the presence of copper in native gold from Australia; in "pure" oxide of silver, purchased from a leading London chemist, as a chemical reagent, &c.

It may be said that copper alone affords this very pyrochrome; but this is not the case, as may be easily proved by heating the point of a piece of new copper wire in a strong O.P., when only an orange (or D line) pyrochrome is afforded for a few seconds, until, suboxide being produced, that is changed to blue-green.‡ The same fact is also strongly indicated by treating with O.P. fragments of various copper minerals. Of eight specimens I thus tried, *Cuprite* was the only one which afforded a perfect blue-green pyrochrome; *Copper glance* and *Malachite* the only two which afforded an orange-green one; the other five emitting (with the exception of *Atacamite*, blue) the ordinary orange pyrochrome.§

By this reaction it is easily seen that the greenish pyrochrome of *Pitchblende* (or *Uraninite*) is not, whatever it be due to, due to copper; by it also may be detected copper in any complexity or multiplicity of combination, for that alone has the power of thus changing the pyrochrome of boric acid, which also never fails to attack it, partly oxidizing it if metallic, and partly reducing a higher than the suboxide. All that is required is, to crush the essay to fine powder, and apply a few specks to an $\text{H}\beta$ glass in O.P. Still greater delicacy of perception is obtained if the operator place a pure $\text{H}\beta$ glass in the same line of fire, but in *front* of the essay.||

It is true that under O.P. copper protoxide affords balls in $\text{H}\beta$, without

* Paragraph (213).

† Page 379.

‡ Paragraph (213).

§ Plattner, however, states (page 381), "In the forceps, cupriferous minerals impart a green tinge to the flame." The student should try for himself, say, *Chalcopyrite* in this way.

|| Paragraph (108), Fig. 63.

altering its pyrochrome, but, as before mentioned by me,* brick red streaks of suboxide are effused from those over the bead or glass by H.P., and contact of a ball with the platinum wire seems to have the same effect, after which the pyrochrome is steadily changed from yellow-green to blue-green. Cuprous, or suboxide, does not form balls, but a red suffusion in $\text{H}\ddot{\text{B}}$, even under P.P.; but if this be continued, small black balls form, in evident proportion to the discontinuance of the blue-green pyrochrome, a phenomenon better seen by using a pyrological candle, in whose pyrocone no sulphur is present to intensify the $\text{H}\ddot{\text{B}}$ green. How far this operation could be carried I do not know, but the cuproborate balls seem a chemical, the cupreous suffusion a mechanical combination; though, on the other hand, the red oxide which has been heated in $\text{H}\ddot{\text{B}}$ becomes a pea-green flocculent precipitate by treatment with water, and is thus readily separated from the cupric oxide balls, which are insoluble in boiling water.

(a) Another extremely delicate and rapid way of detecting copper, is evolved from that of detecting iron.† The crushed mineral, previously roasted, if a sulphuret, is simply placed under a fragment of soda, on aluminum plate, when, even in O.P., the characteristic suboxide appears at bottom of the bead, next the plate. The presence of copper is easily thus determined, even in such minerals (e.g. *Boulangerite*) as contain only a very trifling proportion. If pure lead be added under H.P. on aluminum plate to this *Boulangerite* soda bead, the copper reaction is obscured, a blackish alloy only being found at bottom; but if the bead be now treated with a strong P.P., and kept in fusion from that for some time, it will, on cooling, assume a verdigris green color all over the surface, which cannot be mistaken for ferrisodic green; as even if they were the same tint, this latter is found at bottom after H.P., that over the surface of the bead after P.P. This fact surely indicates a higher oxide of copper than any known. As *Boulangerite*, according to Boulanger's analysis,‡ contains only .9 per cent. of copper, the further addition to the essay of test lead naturally leads to the inference that the test which now detects copper must be a delicate one.

(b) It is obvious that the method of detecting copper by means of metallic tin in borax, &c., could not be easily carried out in an alloy of tin with a little copper; but Plattner§ uses it in that case, only he tells us first to treat the cupriferos tin "with successive portions of microcosmic salt on coal in OF, until nearly all the tin is separated," an operation indicating a great loss of time. If, with a pin's-head fragment of pure tin, a speck of pure copper be fused to a ball, and this alloy treated with O.P. at bottom of a large $\text{H}\ddot{\text{B}}$ bead,

* 'Proceedings Royal Society,' vol. xx., p. 466.

† Bristow, 'Glossary of Mineralogy,' p. 51.

‡ Paragraph (260, a, b, c).

§ Page 378.

the tin is so rapidly oxidized that for some few seconds no green pyrochrome appears, but instead of it, strange to say, a bluish one, something like that of lead; the cuprous pyrochrome then appears, but on examining the bead with a lens, it seemed almost a mass of red copper suboxide, covered with a white scaly coat—apparently stannic borate. This bead seems insoluble in boiling water, but it is disintegrated, the tin part apparently depositing as a pink powder, the copper part remaining a red mass; inside of which, however, was a minute metallic ball, on one side copper red; on the other, the color of dull gold. This alloy, which must have been nearly the composition of “Metal d’Alger,”* is very malleable, being a little less squeezable in the (α) forceps than lead.

(259). COBALTIDES.

In June, 1869, I applied, under an O.P., some pure, chemically-prepared oxide of cobalt to a bead of pure boric acid, supplied as a reagent for separating lead from copper pyrologically, with the Freiberg apparatus. In an elaborate (and expensive) work on Chemistry, then lately published by an eminent English firm, of which I had taken a copy to India with me, I found these words:—“At high temperatures, fused boracic acid *dissolves the metallic oxides to form transparent glassy borates*,† which have in many cases very brilliant colors,” &c. Among such “cases” would doubtless be included the intensely chromatic (when dissolved) oxide of cobalt. It was rather surprising to me, therefore, to find this oxide, instead of dissolving, as the chemist stated it would, forming round black spots in the boric acid, which remained round and *utterly insoluble* in that under any further heat. It was now easy to see (what before, when possessed with the chemical information above quoted, I could not understand) why Berzelius, Plattner, and other pyrologists, had not tried boric acid, *pur et simple*, as a solvent, instead of the salt, borax. It does *not* “dissolve metallic oxides,” &c., pyrologically, but borax *does*. Soda was therefore the principal dissolving constituent, and it was evidently a desirable object to ascertain with *how little* soda, solution of the cobaltine spots (the spherical nature of which I therefore missed ascertaining at that time) could be effected. Cautiously fusing these, with only a few specks of a weighed quantity of sodic carbonate in the bead at a time, I found the cobaltine spots immediately begin to diffuse, until, when 5· per cent. had been added, all were gone. But instead of the *blue* bead which the student of this English Chemistry had a right to expect, the result was a beautiful *pink* one, which the addition of further (to the extent of 5· per cent. I afterwards found) cobalt oxide, converted to pure violet;

* Tin 95·, copper 5·.

† This erroneous statement has been repeated in a second edition of this work, notwithstanding correct information on the subject having been published by the Royal Society in 1872.

a charming bead, which still remains the most beautiful of all the "glasses" pyrologically obtained.

(a) The next step was, to try in the same way the acid constituent of "microcosmic salt," and, fortunately, I had no difficulty in procuring pure "glacial" phosphoric acid, as it was used (at Simla) by the druggist there for therapeutical preparations. Cobalt oxide was now of use to me in determining the purity of this. The shop contained two kinds, one in the shape of ice-like blocks, the other in sticks like those of phosphorus, or of caustic potash. The first formed a nearly blue bead with cobalt oxide; the second, a pure violet one; so that the former was plainly adulterated with some alkali. It was evident that, by adding soda to either pink glass of $\text{H}\ddot{\text{B}}$ or $\text{H}\ddot{\text{P}}$, until it became a perfect blue, I should have to add the proportion of that alkali contained in borax or microcosmic salt respectively, and, therefore, that this would form an excellent alkalimetical process.

(b) A violet glass of either kind is blue while hot, and as the same thing happens to cobalt hydrate alone, it would seem that this is merely mechanically dissolved in that, and the glass not a borate or phosphate of cobalt. As may be seen by the application of its dessicated oxide to $\text{H}\ddot{\text{B}}$, in which the balls emit opaline matter, cobalt has an extraordinary attraction for water, and, as hydrate, can only be permanently dehydrated by substances which have a greater. In solution as nitrate, cobalt hydrate becomes, on a heated slip of glass, first a deeper-toned violet, then, momentarily, blue; and, if the heat be continued, black, probably from the reducing effect of the nitrogen formed. Heated on platinum or other metal, the color changes directly from violet to black. On hard wood, as boxwood, a blue color is seen for a second only. In fact, so far as is known at present, the anhydrous or blue oxide of cobalt has only been formed by fusing the protoxide with glass, when a similar blue to that it forms with borax is obtained.

(c) The chemical account is that there are only two oxides of cobalt, CoO , and Co_3O_4 , which last seems to have been determined on no better foundation than that of the magnetic analogy to iron. The first is supposed to give rise to the beautiful colors obtained from it, without any change in its oxidal composition; but this assertion seems open to serious doubt. CoO , "a greenish-grey" powder, forms, when mixed with water, or any other colorless fluid which only mechanically affects it, a greenish-grey paste; but if a drop of acid or other oxidizing agent be added, the part affected becomes pink. If to the pink spot be intimately added a substance which has the power of chemically absorbing water—as caustic lime—or of passing on oxygen transmitted with heat—as alumina—the pink changes to blue. Finally, if with the blue powder be

ground to a paste a powerfully reducing agent, as calcic hydrate, and the mass strongly heated, the "greenish-grey," or rather black, oxide is again obtained, only it has now a semimetallic look. If all this does not point to a process of oxidation and deoxidation, it must point to Heaven, for it is simply miraculous on any other hypothesis; but the (French) determined atomic weight (59) of cobalt forbids the natural evidence of our senses, while, as to the artificial theory, "the Court awards it, and the law doth give it," so the best thing we can do is to shut our eyes, and allow Nature to be legally executed by Art, for there is no Portia here to prevent the execution. But a still more conclusive proof seems given by the behaviour of cobalt oxide in $\text{H}\beta$ under H.P., to be presently described. It changes from a violet mass *directly* to metallic cobalt, which is thermoelectrically deposited upon the platinum wire, and may be readily extracted by boiling water. Now in this case we have obviously the metal (cobalt) produced by treating the violet oxide with H.P., which reduction cannot be thus effected with the greenish-black protoxide; it seems impossible to doubt, therefore, that these two, at any rate, are different oxides.

(260). FERRIDES.

One of the most delicate reactions* in hydracid chemistry is the potassio-ferrocyanic test for peroxidized iron: it is so delicate as almost to rival some of the pyrological, or even spectroscopical tests: a single drop of the essay solution on a watch-glass is turned a deep-toned blue by the application of a smaller drop of the reagent. But it seems a dangerous operation to employ iron, no matter in what minute quantity, or how chemically bound in the reagent, to detect iron. Practically, great caution is admittedly required in using it. The presence of any free mineral acid in the essay produces a blue color on admission of air, if there be not a particle of iron present in that, and yet the solution must be an acid one. The essay solution "should therefore be previously neutralized or even supersaturated with ammonia, and then acidified again with acetic acid."†

Pyrologically, the borax test for iron (at present used) is a wretched one; a comparatively very large proportion (about 10 per cent.) of the oxide renders the bead yellow, indeed, hot, but almost colorless on cooling; and hundreds of other things do that. Plattner states‡ that such a highly coloring agent as cobalt is removed from an iron borax glass by fusion with "a bit of tin on charcoal in RF," and if the blue of cobalt oxide still appears, he adds, "In this case the glass must be again softened in the RF, mostly removed from

* The test by means of potassic sulphocyanide is also very beautiful, though not quite so delicate as that mentioned in the text.

† Normandy

‡ Page 285.

the coal without any adhering metal, and fused on platinum wire in a pure O.F. In case it should then become so dark as to be nearly opaque, the soft glass is pinched out, some of it broken off upon the anvil, and the remainder diluted with more borax. It is then again treated in O.F. until all the iron is changed to sesquioxide, when it will color the borax yellow to brownish-red, according to the amount present." Those who like to believe that even a considerable amount of iron oxide could thus be detected in a cobalt compound (which often also contains nickel) may do so: I certainly do not, and Plattner seems to me to confess the weakness of the process by adding, "Should there be, besides the cobalt, only a trace [I have before mentioned that "a trace" means at least 5 per cent. of the bead] of iron, the hot glass will be green, but when cold, pure blue."

(a) Now there is a pyrological test for iron oxide existing in any proportion or complexity of combination, so striking, simple, and satisfactory, that it is to me quite incomprehensible how it has escaped such a writer as Plattner. It consists in simply fusing a pin's-head fragment of the essay along with one twice its size of fused sodic carbonate, on aluminum plate, in H.P. If there be iron, although the essay be *per se* infusible, the soda is generally colored by that alone; but if it is not, both it and the essay are to be crushed together in the (α) forceps, a drop of water added to keep the powder from blowing away, and the mass again fused in H.P. to a ball. The slightest proportion of ferric oxide now communicates to the white soda when cold, even in presence of manganese, cobalt, chromium, or other coloring oxide, a yellowish-brown tint: a larger proportion of iron oxide gives it a reddish-brown color. This reaction for iron possesses the delicacy of either, without the danger of the chemist's test, by producing potassium ferricferrocyanide, or the terrible *embarras de richesse* of the 460 ferrospectral⁴ lines. All that is necessary is to hold the essay, which may have in P.P. reacted *turquoise* blue (for manganese) or grey-blue (for cobalt) in a pure candle H.P., when on cooling, those colors disappear from the bead, and that of iron, or sulphur, or ferric sulphide, appears. The operator should therefore invariably employ the H.P. from a pyrological candle, as coal gas always contains sulphur, more or less.

The "hepar sulphuris" of the old writers, as obtained by fusing soda with sulphur in H.P. on aluminum plate,* has, when cold and freshly made, a very beautiful and delicate tint—that of boiled salmon flesh—and if iron oxide be present, and a double sulphide of iron and sodium presumably formed, the general color is not very different, though, in this case, there are spots of green ferric protoxide also visible. This fact, which at first seems injurious to this test, is in

* Paragraph (209, d).

reality advantageous to it, for all other metallic sulphides, except that of iron, are, when reduced in soda by H.P., black, but ferric sulphide in soda cannot be blackened by H.P.

(b) The sulphur reaction with soda, however, is so like that of iron, that the safest way in testing for the latter is always to use a pyrological candle, and, after a strong P.P., in which operation manganese and iron are apparently in part (the first most) converted to an acid oxide, by which manganate and ferrate of soda are produced, the former of which has a perfect turquoise appearance cold, while the latter is, unless my Freiberg reagent is adulterated, pale bluish-green. Cobalt oxide, if present, is very slightly acted on, producing a pale grey-blue or dove color, which does not seem to affect the manganic turquoise in the least. A good candle H.P. now removes the manganic and cobaltine colors completely, the bead, if no iron is present, becoming opaque, snow white; but if there be iron, yellowish-brown on cooling. To confirm its presence, about 1· per cent. of $\text{H}\ddot{\text{B}}$ is fused on aluminum with the bead in a strong O.P., and the result then treated with a pure H.P., when, although the bead has a more decided grey-blue over its upper surface, from the cobalt, when cold, it is quite green hot, and the iron will now be found as green protoxide in a layer at the bottom next the aluminum. As sodic manganate seems also to be thus produced from an oxide, or retained by the addition of $\text{H}\ddot{\text{B}}$ even in H.P., and is then found in the same position, as a darker and more intense green, it is necessary, when these oxides are present together, as in *Asbolane*, to determine the iron, as above described, *before* adding $\text{H}\ddot{\text{B}}$.

(c) In the case of ferric sulphides, the essay is roasted *per se* in a strong candle P.P. on aluminum plate; a drop of distilled water added, and roasting repeated, until, part of the sulphur being apparently volatilized, sulphates are formed, which (as e.g. *Gypsum*), with soda, afford, even after considerable H.P. from a candle on aluminum plate, only a bluish-white, and peculiarly crystalline bead cold,* provided no iron is present, but in the latter eventuality the bead becomes yellowish-brown. Ferric oxide is thus quite readily detected in such minerals as *Smaltite* or *Chalcopyrite*, *Boulangerite*, *Bournonite*,† &c., any copper present being reduced, even in O.P.

Pure piano wire is thus attacked by soda, the use of which, as a reagent for iron, was first suggested to me by a remark of Scheerer,‡ that "oxide of

* Paragraph (118, a).

† *Bournonite* is stated by Dana and the modern mineralogists to contain no iron, because, apparently, the mineralistic formula ($\text{Pb}, \text{Sb} + \text{Cu}, \text{Sb}$) would be in that case spoiled; but Phillips (1823), quoting analyses of Hatchett and Smithson, gives from 1· to 2· per cent. of iron. My specimens from the Freiberg University contain at least that quantity.

‡ Translation by H. F. Blanford, p. 144.

iron is distinguished from other metallic oxides, by forming no incrustation upon charcoal when treated with carbonate of soda." This evidently points to a *solution* of the ferric oxide, which does not apparently happen in other cases, but my experience with aluminum plate as a support, indicates that ferric sesquioxide is very insoluble—indeed, almost unchangeable in P.P.; but that a small peroxidized proportion combines with some of the soda as ferrate, which, when reduced to protoxide by H.P., becomes green beneath. The formation of ferrisodic sulphide, which is apparently rapidly made by adding sulphur, seems to hasten this reduction and solution, which last has, moreover, a more decided color.

A brownish "hepar sulphuris," or sodium sulphide, containing a very small amount of sulphur (which can be made for a pattern by fusing on aluminum plate a piece of soda over a hair of the beard in a candle H.P.), can be readily distinguished from a brownish soda bead containing a little iron oxide—both having been treated in a candle H.P.—by the operator taking the bead between his finger and thumb with a drop of distilled water upon it; the former then smells of rotten eggs, the latter does not. The insoluble part of iron oxide (generally the larger part) is found, either after O.P. or P.P., in that part of the bead which was *next* the pyrocone; in the first case, as a brown; in the second, as a brownish-green sediment.

If silica be present to a large extent in the essay, the sodic silicate formed will of course produce with cobalt a glass more or less blue, concealing the iron reaction; but in this case it is only necessary to crush this glass with the (α) forceps to a fine powder, and to treat this powder in a candle H.P., with an excess of soda, when the iron reaction soon appears; or the greater part of the silica may be previously removed by boiling the crushed essay in $\text{H}\ddot{\text{B}}$ solution.*

To sum up: the soda test for iron depends—1st, upon the solution of a small proportion of (apparently) ferric acid in the soda, which is, however, opaque white after P.P.; 2nd, upon the non-reduction of the peroxidized iron below (at lowest) sesquioxide by H.P.; 3rd, upon the complete reduction by H.P. of all other oxides, including manganese, to some very low oxide, which seems then to collect or aggregate in black or brown particles in the centre of the bead, the surface of which is then, if no iron be present, snow white; but if it be, of a skin or buff tint. The value of this simple test for iron may be concluded from the fact that Plattner, who commences the article by saying that the detection of iron is "very easy," gives twenty closely printed octavo pages, chiefly on modes, wet and dry, of detecting small quantities of iron in compounds.

* Paragraph (218, *g*).

(d) A still more delicate, but less generally useful, reagent for iron, even if it exist in such minute quantity that that of the salt in which it exists is itself microscopic—as, for instance, in the calcium phosphate, evolved (by burning in $\text{H}\ddot{\text{B}}$) from a single grain of wheat—is an anhydrous calcium borate ball, to which the above amount of any iron oxide communicates a green tint when cold; best observed by dipping the $\text{H}\ddot{\text{B}}$ containing the ball in water, when the first becomes opaque and white, betraying the slightest deviation from achroism in the latter. In this manner I easily detected iron in a chemical reagent, labelled “Pure Calcined Magnesia,” in a laboratory. Unfortunately, this most delicate test for iron will not of course answer for detecting a trace of it in presence of the more highly chromatic metallic oxides, but it can be thus perfectly well detected in *Franklinite*, in which case the manganic oxide present fails to overpower the ferric protoxide's green color, even after P.P.

The above described two methods of operating for the discovery of small traces of iron in compounds seem to meet all the cases adduced by Plattner,* in all the more difficult of which, solution of the essay in hydrochloric acid is resorted to.

(e) In $\text{H}\ddot{\text{P}}$, ferric oxides afford a bead or glass having a beautiful red-brown color; seen through which, the platinum wire has a curious appearance, as if bloody water intervened. The addition of lime seems to deepen this tint, and if soda be then added, a reddish mass forms, which may be removed by pliers from the hot bead. In $\text{H}\ddot{\text{B}}$, iron oxide under O.P. forms black opaque balls, which emit a large quantity of brownish-yellow flocculent matter, which seems to be ferric acid, as the same reacting matter is produced by sublimating ferric sesquioxide with lead. Neither of these reactions can be used as a safe means of detecting iron; for, although the first glass is more highly colored by a smaller quantity of oxide than the ferric borax, or microcosmic bead, still a considerable quantity is required before the cold bead shows any color.

(f) If a pin's-head fragment of *Hematite* be heated even in a long P.P. on aluminum plate, it becomes magnetic, and it is difficult to conceive how the chemical formula of that mineral, Fe_2O_3 , can be changed to Fe_3O_4 , the chemical formula of *Magnetite*, in such a phenomenon, which certainly implies oxidation, rather than reduction; but even assuming the latter event to be thus possible, and the atomic weight of iron sesquioxide to be 160; and, further, supposing two molecules of this substance to be converted by the loss of oxygen in reduction, to one molecule of the magnetic oxide, we ought to have $2\text{Fe}_2\text{O}_3 - \text{O} = \text{Fe}_3\text{O}_4$; but this is obviously impossible, as it is also with regard to converting the product obtained by multiplying the atomic weight of ferric

* Pages 284-304.

sesquioxide by any *even* number, or, as it is called, "*ἀπριαδ*," and deducting from that product the proportional weight of the atom or atoms of oxygen said to be removed by heat. It is true that the chemist readily and almost airily explains the (to me) remarkable phenomenon of magnetizing iron oxide by heat, thus: "When the peroxide of iron is heated to whiteness, it loses oxygen, and is converted into magnetic oxide of iron: $3 \text{Fe}_2\text{O}_3 = 2 \text{Fe}_3\text{O}_4 + \text{O}$;" which statement, as heat *invariably* effects the transformation of the ferric, into the ferri-magnetic oxide, seems to involve the other assertions, that heat must be applied to the former substance in the ratio 3 : 2, and that it would be impossible to convert by heating, the exact quantities, $\text{Fe}_2\text{O}_3 \times 2, 4, 8, 16, \&c.$, into proportional amounts of magnetic oxide, which, however, from the evidence of our senses, must be inevitably done.

(g) If a piece of pure lamellar *Hematite* be split along its cleavage planes until a kind of coarse needle be extemporized, and if each end of that be fused (for in spite of the contrary assertion in mineralogical works, even a thick splinter is fusible at the end) in a strong O.P., the two *points* only, possess not merely magnetism, but polarity, while the rest of the needle is, of course, absolutely non-magnetic. Either N. or S. magnetism may now be imparted to *both* points, and the curious fact remains, that such a needle, having thus apparently (though perhaps, not really) two N. poles, each end attracting the S. and repelling the N. of a freely moving compass needle, yet, when suspended horizontally by a fine thread of silk, takes up a position due N. and S. Another similar *Hematite* needle can now be made, having apparently two S. poles, which will also, however, swing due N. and S. It seems to me, therefore, that if such a couplet be placed close together (not connected, of course) in the same magnetic meridian; in whatever way one of them is influenced by local causes, the other will be affected oppositely, and that the mean of their deviations will be the true magnetic meridian; also that some such arrangement might be found useful on board iron ships.

(h) In 1869, when first using glacial phosphoric acid as a reagent, I found that forceps and other steel instruments attacked by it, were attacked only on the surface, a black crust, apparently consisting of eliminated carbon and ferric phosphate being found there after a few hours, when the strongest possible solution of the acid in water had been simply laid on with a hair pencil; that when this crust was scraped off with a smooth hard surface, as the back of a table-knife, a deposition or coating, of metallic appearance, and about the whiteness of tin, was found there; that this coating or plating, although possessed of immense hardness when cold, a point of it easily scratching the hardest steel, seemed *fusible* by such a low degree of heat as that imparted by the

friction of a leather polishing wheel, and could therefore be *spread* by the action of that alone, in a smooth and brilliantly polished layer over the surface; finally, that a steel blade thus plated resisted far more than before the action of water and even of acids upon its surface, which latter, moreover, was so hardened, that by careful setting (not grinding) a cutting edge could be given to the blade, unmatched for smoothness—appearing smooth even under a microscope—and keenness. A razor I treated thus in May, 1870, has been in use every day since then, and on two or three occasions I got three officers to shave with it consecutively, in order to try its edge, which has remained exactly the same as when first set by the assistant superintendent of the surgical instrument department in Calcutta, stropping on clean soft leather only having been practised after shaving. A pocket-knife with two blades, having these phosphorized in March, 1870, was used by me, among other purposes, that year at Dalhousie, in the Himalaya, to cut down saplings of the hardest Indian woods, each about ten feet high; after which I made a pen with the *same* blade. Since then, it has been constantly used by me for mixing chemical salts with (for the larger of the two blades is not much more than a penknife), and all kinds of purposes, and each blade is with the exception of being a little dull, as clean and unworn as the day I bought it. All my table-knives were thus plated in 1870; although fast wearing away in the cleaning before they were phosphorized, they have stopped at that point, and have not worn in the least since then; besides which, they preserve a very brilliant polish, and have a whiter and more silvery lustre than ordinary steel.

A native cavalry trooper's sword, plated by me in 1870, was, in the following year, at Mussoorie, employed by some cavalry officers and by myself, before many witnesses, to cut into a log of *Sissoo*, an Indian wood about as hard as *Teak*, and several of the cuts then inflicted were so severe and deep, that the blade was only extricated with great difficulty. The edge was razor-like in fineness, and was totally uninjured. In this sword the handle, which was unplated, has become red with rust, while the blade has remained *in statu quo*; but the latter has certainly been covered with a scabbard, which is, however, when long unused, often an incentive to rust. A pair of large, common, soft iron scissors became, when phosphorized, in 1870, not merely equal to the finest steel in hardness, &c., but they then received *directly*, on the part immersed in silver solution, an electro deposition of silver, which, in spite of all kinds of rubbings and burnishings, yet remains.

Instances might be multiplied, but these will be sufficient to show that the discovery has every appearance of being practically important and successful; and I was sufficiently foolish to confide it, in 1869, to the subtleties or

mysteries of the English Patent Law, a codification which would disgrace any country in Europe, except, perhaps, Greece. It seems framed to protect rich, unscrupulous men, possessing English legal knowledge; to ruin inventors, ignorant of the hair-splitticisms of that profound science, in direct proportion to the ingenuity and value of their inventions, and to the enrichment of the "patent" lawyers. My specification was returned to India by these gentlemen, to be altered so as to make it absolutely worthless according to the English ex-equity Patent Law, and I thus lost about 40% to them—a sum I could ill afford. The disgraceful case and ruin of the late Mr. Heath, the great inventor of manganizing iron, might have made me more cautious, but I had not then heard it.

(i) The detection of phosphoric acid in iron by $\text{H}\ddot{\text{B}}$ has been described (216, a). Sulphur is detected by the same reagent (Fig. 63) when treated with a *candle* O.P. A shaving of a steel cannon, which I obtained from one of the lathes in the Royal Arsenal, Woolwich, was filed, and a few specks of the powder treated in an $\text{H}\ddot{\text{B}}$ glass under O.P.; a slight quantity of opaline matter, which reappeared after treatment with potash and fresh $\text{H}\ddot{\text{B}}$ (216, c), showed the presence of phosphoric acid; a few balls, reddish-brown but transparent, that of manganese; while the green pyrochrome, visibly increased, indicated that of sulphur.

(261). NICKELIDES.

If the chemists who, following Henry Rose, say that "pure oxide of nickel is of a deep ash grey color, and its hydrate (only) of an apple green color,"* are correct in making that assertion, I can only say that the first may be "hydrated" in the most unaccountable, unorthodox manner it is possible to conceive; viz. by fusing an excess of it with pure lead on charcoal, over aluminum, in a strong O.P., and continuing that, after an alloy has been made, upon the excess of nickel oxide. It seems impossible to imagine, even algebraically, any chemical change by which water could be produced in such an operation. The halo thus produced has a small black nucleus, slightly covered with plumbic yellow, which forms the next ring; then brown, with greenish-white border. But although the hydrate of nickel above referred to, as chemically prepared by precipitation with potash, &c., has doubtless a green color, there can be as little doubt that the suboxide of the metal is also green.

(a) The detection of this oxide, which, when existing in only trifling quantity along with other chromatic oxides, as, e.g. those of cobalt, manganese, or iron, seems a serious difficulty to operators with the blowpipe, who had first to make a *mélée* of all the oxides in several beads of borax, on platinum wire, then to reduce *all* these with an 80 Mgr. ball of pure gold, then to oxidize

* Nood's 'Chemical Analysis,' p. 76.

this latter with microcosmic salt, &c.,* is a matter of equal certainty and rapidity, when the well-roasted (if arsenical) essay is treated in $\text{H}\ddot{\text{B}}$ with O.P. when nickel oxide forms green (metallic in H.P.) *fragments*, but all the others named, *balls*.

(262). URANIDES.

The orange sesquioxide of Uranium sublimated with proof lead on aluminum plate affords a brown halo with yellow nucleus and white border. The latter, scraped off and treated in $\text{H}\ddot{\text{B}}$, does not at first seem to have affected the glass more than the pure lead fume; but the tendency that it has to opalesce, even with excess of $\text{H}\ddot{\text{B}}$ shows that some oxide besides that of lead is present; besides which small insoluble fragments, like those afforded by silica, appear.† (I suspect from other reactions, especially that in $\text{H}\ddot{\text{P}}$, that my "pure" uranic oxide is adulterated with silica.) A lime ball driven through the glass with O.P. collects nothing chromatic from it, but when some specks of the original oxide are added, the ball assumes a yellow-green (E) tint. In $\text{H}\ddot{\text{P}}$ this sublimate is colorless, or perhaps affords a glass faintly bluish. On the whole, it would seem from this, that uranium is one of the few metals which does not send up an oxide with lead in sublimation. Uranic sesquioxide has a decidedly green-yellow pyrochrome. The yellow-green (E) it affords with $\text{H}\ddot{\text{P}}$ can be easily distinguished from the pure green of chromic sesquioxide, or of Vanadic acid in the same reagent; still more easily from the beautiful (Fa) or green-blue of molybdic acid in $\text{H}\ddot{\text{P}}$.

(a) With the spectrum lorgnette, uranic glasses of all kinds, with the exception of the bluish sublimate one above mentioned, afford a characteristic line in "the green," which cannot be mistaken. When the glass is weakly colored, two lines in "the red," the thickest near that of lithia, are also observed. In a strongly colored glass, the whole left and right of the spectrum seem absorbed, leaving "the green" with a thick band in the centre. It is a curious fact, that the $\text{H}\ddot{\text{P}}$ glass containing in solution the sublimate from "pure" uranic oxide + lead affords no spectral lines, while that containing the sublimate from *Uranite*, which has a greenish tinge, shows them strongly.

(263). AURIDES.

The supposed "fixity" and invulnerability of gold under various modes of attack, have rendered it a favourite illustration of some of the "laws" of Nature, not merely with alchemists, but with chemists; with modern as well as ancient philosophers. Paracelsus and Plattner describe in almost similar words the mode of separating volatile alloys from the "noble metal," by means of lead and cupellation. Lord Bacon‡ quotes the properties of gold—"its non-volatility,

* *Vide* Plattner's 'Pröbirkunst,' p. 817.

† Paragraph (218, d).

‡ 'Nov. Org.' ii. 5.

and losing none of its substance by fire"—as an illustration of one means of arriving at Nature's laws. So does Herbert Spencer.* It is, however, well known that gold is slightly volatile when submitted to an intense heat. J. A. Phillips says:† "Gold fuses at a temperature of 1102° C., and when still more strongly heated affords sensible metallic vapours. If a powerful electric charge be passed through a fine gold wire, it becomes entirely dissipated, and a sheet of white paper held beneath becomes stained with a purple line, caused by a deposit of minutely divided metallic gold. If, instead of a sheet of white paper, a plate of polished silver be employed, it is traversed by a brightly-gilded line, which is firmly attached to its surface. A globule of gold exposed between two charcoal electrodes to the action of a powerful voltaic battery, enters almost immediately into fusion, and gives off abundant metallic fumes, by which its weight is rapidly diminished." It will, however, probably surprise chemists, metallurgists, and philosophers generally, to hear that gold can be volatilized, or rather pyroxidized with the ordinary O.P. of a pyrogene, by the very means usually employed to preserve it pure—fusion with proof lead. That gold is invariably, though very minutely, present in the fume from cupellating and other furnaces, has long been known, and the fact is stated by Dr. Percy;‡ but that cupellation should be undertaken for the purpose of detecting gold, not in the residue, but in the sublimate, seems such an inversion of the natural process of art—for what is called "natural philosophy" is very often only artificial—as to be nearly incredible.

(a) It is, nevertheless, not merely a fact, but when the fusion of a gold ball, say of 50 Mgrs., is conducted in a charcoal keyhole mortar on aluminum plate, with about $\frac{1}{10}$ its weight of proof lead, under O.P., the *very first* white sublimate, which is at once evolved, and is ascribed by writers on the blowpipe to lead alone, may be readily proved to contain gold, by the treatment of a little of it scraped off, in a glass of $\text{H}\ddot{\text{P}}$, which, when held in a half-inch P.P., as at 2, Fig. 12, flushes over when nearly cold with the beautiful bluish-violet or (Gδ) tint, so characteristic of gold.

When the O.P. is urged upon the plumbauric alloy with greater power by a table pyrogene, and continued for half an hour, a halo is afforded on the aluminum plate, so beautiful, that I hope I shall be able to get the lithographer to represent it faithfully in this book.§ It is the first instance within my knowledge of the successful securing of an indubitable *Pyroxide of Gold*. This halo, when well made, describes three-fourths of a circle, slightly oblate at the poles of its perpendicular diameter (about 1.25 inch), and elongated at those of its hori-

* 'First Principles,' p. 138.

† 'Metallurgy of Lead,' p. 455.

‡ 'Elements of Metallurgy,' 1874, p. 682.

§ Plate I., Frontispiece.

zontal one. The nucleus, placed nearly at the south pole, is greenish-black; the demilune above that, brownish-black; round the border of this, without a definite shape, but radiating from it with an almost imperceptible loss of tone, till it fades into pinkish-white, is deposited the lovely bluish-violet pyroxide of gold, the whole being surrounded by a white perimeter, as clearly defined as though drawn by compasses. The charming total effect, or *coup d'œil*, as the French say, is that of a rosy morning sky. This auric halo is distinguished even in the process of formation, from the "rose" sublimate of silver (which is due to the trace of gold always contained in it), by the former remaining "blood red" even in O.P., while the latter is then brown, and turns "red" only in cooling; besides, kept for some hours, it turns yellow; the former remaining (Gδ). Treatment of either sublimate in an $\ddot{\text{H}}\ddot{\text{P}}$ glass of course confirms this difference, by the distinctions described under the head of silver.

Pure gold leaf, applied in minute fragments to a bead of $\ddot{\text{H}}\ddot{\text{P}}$, is dissolved by a strong O.P., and, when the bead is afterwards held in a quarter-inch P.P., it flushes over with the (Gδ) tint on becoming cold. If this bead be then crushed in the (α) forceps, dissolved in boiling water, and the solution treated with ferrous sulphate, a curious white, chalky-looking precipitate falls, which, filtered and treated with O.P. on charcoal, shows spangles of metallic gold on the coal, through a lens. A silver $\ddot{\text{H}}\ddot{\text{P}}$ glass, similarly treated, also affords a white, earthy-looking precipitate.

(b) The plumbauric sublimate is best obtained by adding very little lead, and that by degrees, while the reverse is possible with regard to silver, but the largest amount of that is also gained by adding little lead (about .5 per cent.). The outermost, or border halo, though apparently perfectly white, colors, as has been mentioned, an $\ddot{\text{H}}\ddot{\text{P}}$ glass after P.P. just as it is becoming cold, the bluish-violet or (Gδ) tint of auric pyroxide. It will be observed, however, that this beautiful effect diminishes, and even vanishes, on reheating, reduced gold being then seen in small yellow spangles; so that the operator should treat as much as possible of the highest or border sublimate in a largish $\ddot{\text{H}}\ddot{\text{P}}$ glass, held in a short P.P.,* and not attempt to repeat the operation, unless, of course, no color has been obtained, which is very unlikely. The reason of this seems plain. The auric oxide dissolved in the plumbo-phosphoric glass has an extraordinary tendency to be reduced, even in a long P.P., if continued, for small balls of a yellowish alloy may be seen floating in the clear glass when it cools; and these balls can only with difficulty be reoxidized by fresh $\ddot{\text{H}}\ddot{\text{P}}$ and a long P.P. The same fact is observable with regard to platinum, only in that case the reduced platinum

* Fig. 12, 2.

is found, not as an alloy in the form of balls, but as spongy, metallic-looking fragments clinging round the wire.

(c) Since writing the above, I have been informed by Mr. R. Smith, of Dr. Percy's laboratory, that the invariable presence of unweighable gold in lead fume is proved by *burnishing*; also that the rose sublimate supposed to be derived from silver is sometimes found in the cupel in the large scale; that it has not been described (it is not even mentioned!) by British chemists, because no certain proof has been obtained as to what it really is; finally, that the only published description to be found of it is that given by Plattner.

Taking these facts, in conjunction with those ascertained by myself—viz. that the rose sublimate, as above described, is obtained much more strongly from gold than from silver on aluminum plate; that the latter sublimate changes color (to brownish orange), while the former does not; and that this remains pink under O.P., while that is then brown—into consideration, I came to the conclusion that the "rose" sublimate is that of gold, *not of silver*, which is brown-orange; that *all* silver, therefore, contains a trace of gold, and that all lead contains a trace of auriferous silver. In order to test this conclusion, I fused a ball of pure gold with a very small proportion (about .5 per cent.) of pure silver, and an equally small quantity of test lead, on charcoal over aluminum plate. For it seemed to me that the silver would thus volatilize with the lead alone, while the gold mass would have a tendency, at least, to retain *all* auric traces in the silver lead. In this experiment I was only partly successful. A halo was obtained on the aluminum, chiefly brown-orange with white border (silver), and a chocolate-brown nucleus (lead pyroxidized by P.P.); but on each side of the bottom of the nucleus was a rose tinge, explainable, indeed, on the supposition that the pyroxidation had been driven too far; but, on the other hand, the residual gold ball (which was covered with crystalline planes on cooling) was whitish-yellow, and evidently still slightly alloyed with silver. On the whole, however, I submit that these facts confirm the hypothesis of the *rose sublimate being due to oxide of gold*. A pure plumbargentic sublimate can be obtained as described in Paragraph (243, k, 2).

(d) The detection of uncombined gold, although existing in very minute quantity, is so easily and certainly made by means of the mechanical process of crushing the quartz to a fine paste, first with the (α) forceps, and then between agates with water, and finally examining the wet dust with a lens or microscope, when the smallest metallic specks are discovered flattened out in yellow plates, that it seems scarcely requisite to give directions for the detection of still more minute traces of the noble metal, which may, however, be made as follows. A fragment of very poor gold quartz, showing nothing metallic microscopically,

is crushed to paste as above described; any flat specks of gold are then picked out under a lens, with a fine-pointed pair of forceps, or a needle with the point wetted, and a drop more of water added to the remaining paste, which is again ground, and (if any are discernible) all metallic specks similarly removed. A charcoal mortar is then charged with the paste and test lead, as described in the article on "Lead Fuming,"* and a transparent yellow bead of plumbic silicate formed, which is microscopically examined for any minute balls of gold or copper-gold which may have been reduced in the process. If such do not appear, that is still no proof of the absolute absence of gold; for I have observed in a plumbic silicate bead, the size of a small pin's head, a distinct bluish-violet tinge over part, due to the presence of auric oxide. The bead is then carefully crushed with the (α) forceps, and the powder fused with fresh test lead on aluminum. An $\ddot{H}\ddot{P}$ glass, treated with the white border of the resulting sublimate, will generally become pinkish when cold. It is then held over an equally weak shade of (E),† when the complementary result will be 1··9, or "rock tint."‡ A further proof of the presence of gold is obtained by treating this glass with H.P., when it becomes dim, and bluish by transmitted light; a result only obtained with auric and platinic oxides.

(e) In the above citations from Mr. Phillips's work it will be seen that he assumes the "purple" powder obtained by "dissipating" fine gold wire in the electric arc to be due to "a deposit of minutely-divided metallic gold"; and this opinion, which is generally held by metallurgists and chemists, is in accordance with certain experiments of Faraday. It seems however, beyond all reasonable doubt, to be the fact, that the bluish-violet or rose color obtained from gold in different ways, is really an oxide of that metal, and the chemist or metallurgist can satisfy himself of this fact by a modification of the operation above described, i.e. treating a little of the *white* or outer part of the gold halo on aluminum plate in $\ddot{H}\ddot{P}$, but under a long O.P. (for a short O.P. would make the whole bead dim), as 1, Fig. 12. Gold is then microscopically discovered in the bead or glass (for either shape will do) as minute yellow spangles, while that remains clear and perfectly colorless. When, however, the glass is removed to the position 2, Fig. 12, or is, in fact, peroxidized, the rose tint flushes over it in becoming cold. There thus appear to be, to the candid observer, *two* pyroxides of gold: (a), white; and (b), bluish-violet.

(f) Dr. Percy has not, apparently, been successful in obtaining this rose sublimate from silver, as may be gathered from the expressions used in his letter to me, already quoted under the head of Silver,§ but, considering I painted the top of my letter of inquiry to him, with a brownish-pink square of

* Paragraph (129, c).

† Plate II.

‡ Plate III.

§ Page 252.

sublimate derived from the fusion of a ball of pure silver with a trace of the Freiberg *probir blei* on aluminum, I cannot understand his strongly-expressed opinion on the subject, for it seems (to me) quite impossible to fuse silver with lead on charcoal over aluminum plate, without obtaining the rose sublimate more or less strong; though, as I have above shown, there can be little doubt that the latter is due, not to silver, which has its particular pyroxide, but to gold, which is always contained in silver, and generally, also (apparently), in platinum. I see that in the new edition of his splendid work on metallurgy, about to be published in the spring (of 1875), Dr. Percy cites gold as an example of a "*fixed metal*," which it certainly cannot be practically called, as fusion with lead, at even a moderate heat, causes it, as we have seen, to be partly sublimed with the pyroxide of the latter-mentioned metal, while each increase of heat applied to the alloy, seems to proportionately increase the amount of auric sublimate.

(263). PLATINIDES.

At Simla, in the Himalaya Mountains, in 1869, I found that pure powdered *Graphite*, dissolved in a bead of phosphoric acid on platinum wire, violently attacked the latter. In the hope, therefore, of obtaining a pyrogenical oxide of this metal, I treated thin strips of its foil in $\ddot{H}\ddot{P}$ on charcoal, with a strong O.P. An oxide, indeed, was evidently obtained; the flux then becoming moderately green while hot, and, after H.P., dim and purplish-blue on cooling, very much like the behaviour of pure gold dissolved in $\ddot{H}\ddot{P}$ alone.* But this was not all; although under the disadvantage of having only a mouth pyrogene, the foil was with some difficulty fused into a ball, having exactly the color and lustre of platinum, but brittle under the hammer. I found afterwards, that long treatment with $\ddot{H}\ddot{B}$, removing the $\ddot{H}\ddot{P}$, rendered it malleable, but infusible again. By adding small portions of the foil at a time to $\ddot{H}\ddot{P}$ on charcoal, and blowing for some hours, I eventually obtained a platinic ball, about the size of a large pin's head, having a smooth bright surface. This was a curious result of treatment with such a highly oxidizing substance as phosphoric acid under O.P.; seemingly explainable by a hypothesis of the formation of (*a*) a platinic carbophosphate (the composition of the "slag" or bead); and (*β*) a platinic carbophosphide (the composition of the metallic ball).

(*a*) The ball (*β*) being kept with the bead (*a*) for some time, white hot, in front of a powerful O.P., and left to cool gradually, covered by that, *crystallized* over the covered surface, in (apparently) hexagonal or pentagonal planes; but Professor Miller (to whom I sent the first crystal made) expresses his belief that the crystallization is in the cubic system. The exposed part of the surface

* Paragraph (153, *d*).

remains smooth on becoming cool. In further experiments, carbonic phosphide was first formed by the process described above, and the platinum foil treated under O.P., in the clear bead on charcoal. Although these investigations have not yet been controlled by the use of a balance ($\text{H}\beta$ being so inconvenient, on account of its rapid deliquescence, to weigh), about $\frac{10}{1}$ in weight of this flux seems the proper proportion to fuse, in the first place, platinum foil before a pyrogene on charcoal; but after a ball of that is once thus made, it will take up a considerable further proportion of platinum, added to it in the same amount of carbonic phosphide under a strong O.P., on charcoal. The fact, however, is here to be observed, that if the proportion of platinum thus added prevails, the more decidedly cubical is the crystallization in cooling; while, if the proportion of flux predominates, the resulting crystalline forms on the surface of the ball seem to belong more to the hexagonal system; but these are questions to be decided only by the crystallographer, and Professor Miller has promised me some measurements of the crystallized platinum first obtained.

(b) Platinum fused, in about equal proportion, with pure gold on a charcoal mortar over aluminum, affords an extremely thin, pink, semimetallic-looking sublimate, almost identical with that spread over the plate by the fusion of "pure" silver, *alone*, similarly treated; which fact seems another proof that the pink sublimate is due to gold; no silver (on this hypothesis) being absolutely free from gold. The theory seems, that a mere trace of gold in a ball of pure silver, is eliminated by O.P. on this support, and spread over the plate in the form of the pink pyroxide.

(c) Platinum fused as above, with about one-third its bulk of pure silver, affords a golden-bronze, semimetallic-looking sublimate, which is the true one of silver, in which there is no auric or pink tinge.* The addition of about 1 per cent. of lead very much increases the volume of this argentic sublimate, but pyroxide of gold is then, also eliminated, as there is now a faint pink tinge. The order of the resulting halo is as follows:—(1) A red violet ($\text{H}\beta$) nucleus, which changes after some hours to a brilliant orange. (2) The first ellipse above that, a greenish-brown. (3) Second ellipse, round [2], pinkish-brown. (4) Third ellipse, round [3], the golden-bronze or true argentic sublimate. There is no white border. If the O.P. has been very strong (proved by the white-hot glowing of the essay), metallic splashes are found over the whole halo, and even far above it. If no lead has been used, the golden-bronze sublimate gives in $\text{H}\beta$, silver reactions only; but with lead, transmitted light shows a faint pink tinge in the glass (trace of gold). The golden-bronze

* Paragraph (243, 4).

sublimate treated on the aluminum as it was deposited, with H.P., becomes white and metallic looking, like silver, but seems to be not that, but an oxide.

(d) Fused with about an equal bulk of pure gold, and about 1· per cent. of lead added to the alloy, platinum affords an indistinctly reddish and brown sublimate, with white border, which does not *appear* to contain much gold, i.e. has little bluish-violet tint, but a little of the outer part scraped off and treated in $\ddot{H}\ddot{P}$ affords a glass which not only becomes beautifully colored ($H\gamma$) on cooling, but contains (comparatively) large, dark, semimetallic, unalterable masses floating in it, which can be nothing but spongy platinum.

(e) Platinum fused as above, with just sufficient test lead to enable it to form a ball, yields an uncharacteristic halo not unlike that of lead alone, having, generally, a chocolate brown nucleus, with a white border; but a little of the latter treated in $\ddot{H}\ddot{P}$ invariably (at least it did so the six times I tried it) affords to a half-inch P.P. a glass which becomes pale pink on cooling, though this color vanishes on re-treating, and cannot be again produced. It seems due to the presence of traces of gold even in the purest platinum, for the glass afterwards affords the reactions of platinic oxide as above described, and if the pink tinge were due to that, it would be much more strongly determined. The reaction, however, taken in conjunction with the others, is a good test for platinum, because a gold ore, or auriferous silver, &c., would afford ($H\gamma$) of a much more decided tone.

(f) I regret that, with reference to the platinic crystal (the first apparently ever produced artificially) referred to in (a), Professor Miller has been unable to send me the promised measurements; but it will be seen from the following extracts from a last letter to me, dated 19th November, 1874, that the undertaking is a much more arduous one than was to be expected from the apparently regular and perfect nature of the crystal, which, though only the size of half a pin's head, has the appearance, under a microscope, of a beautifully cut, though opaque diamond, the surface presenting an unbroken succession of glittering facets. After stating in a letter to me, dated 14th September, 1874, that "I extended the number of faces to-day to 138" (!), he says, "I believe several faces remain still unobserved. The position of each of these faces observed is recorded by two angles corresponding to co-latitude and longitude on the face of a globe." The letter first mentioned, says: "About a third of the work of reducing the observations of the faces of the platinum globule, preparatory to projecting the poles of the observed faces on a stereographic projection of the sphere, has been completed. I am convinced that the faces observed do not all belong to the same crystal. I cannot yet tell how many crystals have combined to pro-

duce the resulting globule, until the poles of the faces are projected." In a former letter to me, dated 18th August, 1874, Professor Miller observed: "I mounted the globule of platinum on the goniometer, and made measures of upwards of sixty faces, but in consequence of the faces being many of them nearly alike in shape and very small, I obtained no satisfactory result. I think, however, that by screwing a small reflective goniometer to the circle of a goniometer of twice the size, with its circle horizontal, I shall be able to obtain for each face, readings like altitude and azimuth, by which I can obtain with considerable accuracy the position of each face. The number of faces, belonging I presume to different crystals, is enormous."

(264). OSMIDES and IRIDIDES.

Mr. George Matthey, of the firm of Johnson and Matthey, was good enough to give me two small specimens: one labelled "Pure Iridium," the other "Osmium Iridium," which latter was stated to be the native *Iridosmine* (Bristow), but fused, I presume by the oxyhydrogen apparatus, into pellets about the size of a buckshot. Having only received these after part of this work had gone to press, I could not do more than cursorily examine them by my methods.

The first named of these is a semimetallic looking, heavy, grey-white substance, and, what I did not expect to find, *soft*; being easily scratched with a penknife.

The second is shining, metallic, very heavy, very hard, brittle, and about the color of tin. When broken with a hammer (which there was some difficulty in doing) the fracture showed numerous gas-cavities.

Both of these seemed unassailable in $\ddot{H}P$, and even in $\ddot{H}P$ on charcoal, which so rapidly attacks platinum. They appeared, also, to be unattacked when fused with lead on charcoal over aluminum, in which eventuality, they are the only really "fixed" metals within my knowledge, but I have not had time to examine them properly.



(265). *The Student of the Science of Pyrology, having advanced thus far in the prosecution of that subject, is in a position, not merely to appreciate its importance as an agent of purely scientific, or generally analytical inquiry, but to discern the probable value of its application to matters, such as those briefly indicated in the following, final pages of this work, where its aid has been hitherto, either little appealed to, or altogether ignored.*

(265). THE MANUFACTURE OF ARTIFICIAL GEMS.

There are at least two new ways of pyrologically imitating these beautiful productions of nature: (1) by coloring the balls formed by adding caustic lime to beads of $\ddot{\text{H}}\ddot{\text{B}}$, and coloring those as required, by taking up during fusion different metallic oxides in a state of fine powder, when the colored ball, extracted by boiling water, will be found sufficiently hard to scratch glass, and quite durable; (2) by coloring an $\ddot{\text{H}}\ddot{\text{P}}$ bead with the required oxide, and then gradually taking up pure powdered silica, also under fusion of O.P., but on the "off" side, so that it may be protected from this, which would render it nearly insoluble in this flux, until the bead is supersaturated with silicic acid, but still transparent, when it is no longer subject to atmospheric influences. Borax, which is much less acted upon by moist air than $\ddot{\text{H}}\ddot{\text{P}}$, answers this purpose very well, but the colors produced are neither so intense nor brilliant, while some, as the cobaltine violet, cannot be produced by it at all.

I placed on a sheet of white paper before Colonel Gordon, Director of Artillery Studies, R.A. Institution, Woolwich, some colorless calciboric balls made as in (1), along with Mr. Hunt's uncut diamonds,* and asked him to select the real diamonds; whereupon he selected some of the balls that I had made, and left the real diamonds and some zircons behind.

(a) On the present mode of manufacturing "paste," we may accept the admirable description of Mr. Porter † as being essentially still in vogue and correct. According to four out of five paste compositions given by him, those may be generally, without any important error, termed silicates of lead; while the fifth seems to be a boro-silicate of sodium and potassium. These compositions must be kept in a melted state (in a proper crucible) from twenty-four hours to three days, "to perfect the refining, and to cause the dissipation of the superabundant alkali;" this is the account quoted of the processes of a Frenchman, M. Loysel. Mr. Porter says, however, of these, "The best of these mock diamonds require, indeed, the aid of artifice in the mode of their setting, to render them in any degree ornamental;" but a final paragraph, written apparently by the editor of a new edition, states: "It is said that the present director (1852) of the national works at Sèvres has discovered a method of making rubies, which, whether tested by their brilliancy, hardness, or specific gravity, are not distinguishable from real gems." Mr. William Griffin informs me that another Frenchman has made a precisely similar discovery now (1874), which is probably of about equal value.

(b) Without for a moment pretending that my methods can rival these important, though unknown, discoveries, and with the further excuse that the first are almost entirely undeveloped, as I was far too busy with their scientific

* Paragraph (257).

† 'Manufacture of Porcelain and Glass.'

results to point out commercial ones, however elegant these might be, I can honestly recommend to the amateur this very beautiful art; more especially, as the colors thus obtained from cobalt oxide are very different, and more beautiful than the "blue" hitherto universally obtained from it. To do this mode of imitating gems justice, however, a bead of Hb not less than a pigeon's egg should be employed, and fused by a pyrogene of correspondingly large size: to this, a fragment of perfectly calcined (in a platinum hook) lime, the size of a small bean, should be added, under O.P. We should then obtain a lime-borate diamond the size of a pea, and as this substance scratches glass with ease, it could probably be cut and polished by the lapidary.

(266). THE MANUFACTURE OF METALLIC OR MINERAL PIGMENTS.

These are rapidly, cheaply, and easily produced by volatilization of the metal or mineral, either *per se*, or fused with pure lead on a charcoal mortar supported on aluminum plate, according to the color and nature of pigment required. The resulting colored sublimate is then gently scraped off the aluminum with a sharp but smooth-edged penknife, transferred to a clean agate slab, and there ground by another polished agate with the ingredients necessary to contribute fixity, &c., to the color.

The subject has been little investigated as yet, but it is evident that almost any required tint may be thus produced by a careful selection of the material, while the fine state of division in which chromatic oxides are thus produced cannot be surpassed, if equalled, by any other method. Following is a list of the pigments I have had time to produce, described, for the present, as nearly as possible, by the conventional terms in use. The pigments were mixed with distilled water on the plate of aluminum upon which they had been sublimated, and transferred thence with an ordinary paint-brush to a pocket-book of ruled, and not very white paper, after which the squares of color thus made were covered with a coating of unpurified gum; so that it will be seen that the method has not here had fair play, and that the colors described must be held as only an approximation to the truth.

(1) Lead fume; brownish skin color. (2) Pure zinc; sandstone yellow. (3) Lead + zinc; skin color. (4) Lead + marble; pale brown. (5) Lead + caustic lime; brownish-grey. (6) Lead + silica; white-grey. (7) Lead + alumina; reddish skin color. (8) Lead + silver; nut brown. (9) Lead + manganic dioxide; yellow-brown. (10) Lead + magnesia; brown-yellow. (11) Lead + baryta; greyish-brown. (12) Lead + potassic carbonate; European skin color. (13) Lead + sodic carbonate; pinkish-brown. (14) Lead + lithic carbonate; grey. (15) Lead + gold; bluish-violet. (16) Lead + platinum; straw-yellow. (17) Lead + cobalt (metallic); vandyke brown. (18) Lead +

cobalt oxide; brown-orange. (19) Lead + *Uraninite*; grey-brown. (20) Lead + copper; bark-brown. (21) Lead + uranic oxide (chemically prepared); chocolate-brown. (22) Lead + nickel oxide; yellowish-white. (23) Lead + nickel (5 per cent.) and cobalt oxide; pale yellowish-brown. (24) Galena; greyish-white. (25) *Uraninite*; earth-brown. (26) *Molybdenite*; greenish-indigo. (27) *Wulfenite*; grey. (28) Tellurium; black-grey. (29) Selenium; neutral tint.

(a) Every one of these sublimates afforded *also* a white pigment from the margin; the color described being taken, in most cases, from the *nucleus* of the halo formed, although sometimes that was perfectly black, affording therefore a fine metallic black pigment.

(b) It would appear that pigments thus produced (and doubtless many others, as reds, might be devised by the addition to the essay of sulphur, &c.) might be especially suitable for enamelling, painting on glass, and similar processes, as, having withstood such an amount of heat in the first instance, or as the manufacturer would say, "having been well burned," they would in all probability remain "fixed" throughout any further application of fire; but a great deal of empirical illustration is yet required, and in this it should never be forgotten that both porcelain and glass are fluxes, having an essentially *alkaline* reaction.

(267). SEPARATION OF METALS IN ALLOYS.

This process depends on the curious fact that almost every metal, although combined in an alloy, possesses, for the most part, a different attraction for heat, and may be caused, by the gradual application of this to the alloy ball when in a hot, but not fluid, state, to *advance its particles towards the source of heat*, leaving those of another metal or metals, possessing a less attraction, on the "off" side, or that *away* from the source of heat.

Long ago, the great English philosopher Boyle "suggested several considerations why even the most solid bodies should be thought to have an intestine motion. This he instanced particularly in a diamond he wore, which had a spot in it that he could sensibly perceive to change its place;"* but the fact does not seem to have been confirmed by any other observer since, although Newton appears (by the work cited below) to have gone through a great many of Boyle's experiments.

I have not had time since to confirm the experiments I made at Mussoorie, in India, in 1871; but the fact above described is beyond all doubt, and may be thus proved. If a ball of gold and silver alloy be placed upon a half-inch *cube* of charcoal held on the point of a needle (Figs. 46, 47), and treated with a long P.P., as at 3, Fig. 12, the side of the ball next the heat will, after a short time,

* 'Boerhaave's Theory of Chemistry,' p. 223, Eng. trans. London: Longman. 1727.

be found silver-white, and the "off" side, gold-yellow. I much regret that I cannot at present put my hand on the notes of my experiments in 1871; but I remember cutting such a separated alloy ball in two with a penknife, and finding the gold extending from the back to the centre, or, in fact, retaining the coolest position in the ball, which must on no account be heated sufficiently to render it *fluid*, as in that eventuality it spins round, and the separated metals are immediately mixed together again. The same phenomenon is observed in any alloy, as, for instance, in the similar treatment of a common pin fused to a ball, in which (if I remember right) tin is found in front, and copper behind. Such a phenomenon may afford the true *rationale* of Pattenson's process of desilverizing lead, for in that, as must not be forgotten, it is essential that the iron ladles used in the operation of "skimming" the melted alloy, be *kept hot* in a small "temper pot" containing lead in a state of fusion. Now, lead has a far greater attraction for heat than silver has: a ball of it which has been fused by O.P. on charcoal remains soft, and indeed, fluid, during a length of time in which a ball of pure silver, fused under precisely similar conditions, has become nearly cold. It does not seem very foolish to conceive, therefore, that the fluid but cooling lead is attracted by and clings to the *hot* ladle, crystallizing thereupon as it becomes cold, while the cooling but hot fluid silver is left behind. It would be interesting to see if the converse of Pattenson's process—i. e. an *ice-cold* ladle plunged into the large pot of fluid alloy—would attract silver from that before it became too hot. At any rate, silver may be certainly (and far more safely than in cupellation) separated from a plumbic alloy, by treating that as above described with P.P. and dipping the lower part of the charcoal mortar in a cup of cold water, when the lower part of the alloy, after the process has been often repeated, will be found to consist of nearly pure silver, the lead collecting at top with a lithargic crust over its surface.

(268). AGRICULTURAL AND HORTICULTURAL ANALYSES.

Mr. Nesbit says, in his 'Lectures to Farmers on Agricultural Chemistry,'* "Adulterations of guano are carried on to an extraordinary extent. The other day I happened to be in Newcastle, and I can assure you that there is a regular establishment there for the purpose of sending into this neighbourhood, and into Hull, Stockton, and other places, systematically adulterated articles to the extent of thousands of tons. They are sent off quietly to prevent the trickery from becoming known, and are, of course, flavoured with a little genuine guano. . . . The quantity of adulterated guano annually made up cannot, I think, be less than 20,000 or 30,000 tons, and I estimate the lowest amount of which the farmer will thus be defrauded at 100,000*l.* per annum." In

* Page 32.

another part of this work the same writer gives us the following "composition of a sample of *fertilizing powder*, at the price of 20 shillings for 4½ pounds weight":

Silica	6.45	Potash and soda	0.92
Moisture	4.91	Sulphate of lime	1.71
Organic matter	25.79	Phosphate of ditto	0.96
Nitrogen	1.47		
Carbonate of lime	55.59		<u>97.80</u>

And he adds: "You must all consider the article too dear at the price." Again he warns the farmers, at page 50, thus: "In the first place, you should only deal with men who have a character to lose. In the second place, you should not neglect to avail yourselves of the security afforded by analysis."

(a) Now the chemical analysis of manures, &c., is, at best, a filthy, and therefore an expensive, business, for it is not likely that the generality of farmers or gardeners would be either able or willing to perform it themselves; but if they reflect, (a) that *every* plant or vegetable shows, by the ultimate pyrological decomposition of the minutest particle of any part, residual mineral constituents of that part; and (β) that these mineral constituents are evidently of the same nature as those contained in the soil in which the plant has sprung, and must, therefore, have been derived from that, farmers and horticulturists generally will easily see that the best and most reasonable chemists to employ are *the plants themselves* (i.e. quickly growing weeds or fungi), for *they* will perform this nasty, but indispensable, analysis in the most perfect and elegant manner, gratis, if planted in a sample of the manured soil it is proposed to employ, and yield up the whole secret of their analysis in the course of a few minutes, to the pyrological farmer or gardener with his "blowpipe" and boric-acid bead. It has been incidentally mentioned in the course of this work * that organic substances, whether vegetable or animal, afford, when heated in $\ddot{H}\ddot{B}$ under O.P., direct evidence of the mineral nature of their (apparently) basic constituents; and throughout the whole book minute directions are given, under the separate heads, for determining and confirming the precise nature of these constituents, so that more detail need not be here given, than that the operator, having fused a bead or glass (the latter form obtains results more rapidly)† of $\ddot{H}\ddot{B}$ on platinum wire, takes upon it, when red hot, the essay, which may be, for instance, a bag or pericarp of the *Capsella* (shepherd's-purse), or common chickweed (*Stellaria media*), or a grain of wheat. If quantitative analysis be not in view, the O.P. is directed upon the essay, which is then rapidly burned, although thus minute specks of the charred fragment are liable to be blown away by the superposed blast from the pyrogene. The residue is the mineral part of the essay—generally calcic or magnesian

* Paragraph (66).

† Vide Paragraph (140).

phosphate, with silica, alumina, and free phosphoric acid—and appears in the HB bead or glass in the shape of balls, fragments, and opalescence.

(b) Chaptal * quotes from Th. de Saussure, tables, from which the following items are extracted :

TABLE VIII.

	Ashes in 100 Parts of Dry Plant.	Salts Soluble in Water.	Earthy Phosphates.	Earthy Carbonates.	Silica.
(1) Leaves of the oak (<i>Quercus robur</i>), May 10	53.	47.	24.	12.	3.
(2) Ditto, on September 27	55.	17.	18.25	23.0	14.5
(3) Stems of young oaks stripped of bark ..	4.	26.	28.5	18.25	0.12
(4) Bark of above-mentioned stems	60.	27.	4.5	68.25	0.25
(5) Wood of oak separated from the alburnum†	2.	38.6	4.5	32.	2.
(6) Alburnum of wood above mentioned ..	4.	32.	24.	11.	7.5
(7) Bark of trunks of oaks above mentioned..	60.	7.	3.	66.	1.5
(8) Liber of the above-mentioned bark	73.	7.	3.75	65.	0.5
(9) Extract of wood of above-mentioned oak	61.	51.			
(10) Mould of oak wood	41.	24.	10.5	10.	32.
(11) Extract of the above mould	111.	66.			
(12) Leaves of the poplar (<i>Populus nigra</i>), May 26	66.	36.	15.	29.	5.
(13) Leaves of the same, September 12	93.	26.	7.	36.	11.5
(14) Trunks of the poplars stripped of bark, September 12	8.	26.	16.75	27.	3.3
(15) Bark of the same trunks	72.	6.	5.3	60.	4.
(16) Leaves of the nut tree (<i>Corylus avellana</i>), May 1	61.	26.	23.3	22.	2.5
(17) The same washed with cold distilled water	57.	8.2	19.5	44.1	4.
(18) Leaves of the nut tree, June 22	62.	22.7	14.	29.	11.5
(19) The same, September 20	70.	11.	12.	36.	22.
(20) Branches of same tree stripped of bark, May 1	(?) 5.	24.5	35.	8.	0.25
(21) Bark of same branches	62.	12.5	5.5	51.	0.25
(22) Wood of the mulberry (<i>Morus nigra</i>), no bark, November	7.	21.	5.25	56.	0.12
(23) Alburnum of the same	13.	26.	27.25	24.	1.
(24) Bark of the above branches	89.	7.	8.5	45.	15.25
(25) Liber of the bark	88.	10.	16.5	48.	0.12
(26) Plants of the garden bean (<i>Vicia fabia</i>), May 23	(?) 150.	5.55	14.5	3.5	1.5
(27) The same while in flower, June 23 ..	122.	55.5	13.5	4.12	1.5
(28) Seeds of the same (beans)	33.	69.28	27.92		
(29) Plants of wheat (<i>Triticum sativum</i>) in flower	..	43.25	12.75	0.25	32.
(30) The same bearing ripe seeds .. .. .	..	11.	15.	0.25	54.
(31) Grains selected from the above wheat ..	13.	47.16	44.5	..	0.5
(32) Wheat bean	52.	4.16	46.5	..	0.5
(33) Plants of maize bearing ripe grain ..	46.				
(34) Grains of the above maize	10.	62.	36.	..	1.
(35) Straw of barley (<i>Hordeum vulgare</i>)	42.	29.	32.5	..	35.5
(36) Grains of barley separated from above straw	18.	22.	22.	..	21.
(37) Oats	31.	1.	24.	..	60.
(38) Leaves of the <i>Rhododendron ferrugineum</i> , growing on Jura, a calcareous mountain	30.	23.	14.	43.25	0.75
(39) The same, growing on Breven, a granite mountain	25.	21.1	16.75	16.75	2.
(40) Golden rod (<i>Solidago vulgaris</i>), before flowering	92.	67.5	10.75	1.5	1.5

* Agricultural Chemistry, p. 176.

† That part of the wood in which no coloring matter is yet deposited, which is interposed between the bark and *duramen*, is called alburnum. Lindley, 'Intro. to Botany,' p. 94.

(c) In 1874 I sent to Leicestershire for some specimens of wheat grains, good, bad, and indifferent. Of these the following analyses are submitted, not as being in any way complete, for as this mode of analysis was only lately discovered, there was nothing like sufficient leisure allowed the writer to develop it in time for the publication of this work; but in the hope that the few examples given will arouse the interest of the farmer, horticulturist, agricultural chemist, &c., and lead them to make further experiments in this direction.

A. A grain of good plump-looking *wheat*, grown by Mr. Beale, Warwickshire, harvested in 1873.

(1) The grain, taken on a red-hot $\text{H}\ddot{\text{B}}$ bead was treated with O.P.

(a) Burned quietly without much gaseous flame.

(b) Minute opaque white balls in the black charred mass, some apparently of moisture, as they seemed to burst on cooling; could not succeed in getting a reaction from them with test paper; others had a glassy texture, and seemed to be calcic phosphate. The carbonaceous part stood a very strong O.P. for three minutes. (This latter fact seems to indicate *Nitrogen*.*)

(c) Four opaque white balls formed in the $\text{H}\ddot{\text{B}}$, with considerable opalescence (free phosphoric acid). The former completely dissolved with much opalescence in continued O.P., showing them to be chiefly composed of calci-silico-phosphate, for calcic phosphate alone could not have been thus decomposed, and magnesian phosphate not even when in combination with silica.

(d) On adding fresh $\text{H}\ddot{\text{B}}$ many balls re-formed, but *clear* (anhydrous calcic borate), and far smaller and more scattered than before.

(e) Green $\text{H}\ddot{\text{B}}$ pyrochrome slightly orange (free soda).

B. A grain of very bad *wheat*, shrivelled, and not much larger than a grain of mustard seed. Harvest on Mr. E——'s farm, 1873.

(1) The grain treated on $\text{H}\ddot{\text{B}}$ in O.P. as before, burned with emission of much gas.

(a) *Clear* balls after effervescence (Calcic carbonate) with a quantity of hard undigested (insoluble) silica, fat-like fragments of alumina, and little opalescence (no free phosphoric acid).

(b) Green $\text{H}\ddot{\text{B}}$ pyrochrome *more* green (presence of KO. and no soda).

C. Another grain of the good *wheat* burned with emission of gas, and gave many of the minute glassy balls mentioned in (A, b). It also afforded a number of balls in $\text{H}\ddot{\text{B}}$, but all opaque, white, and *none* clear. It seemed evident, from these two simple experiments, that the grower of (B) wheat (Mr. E——) had

* Paragraph (211, b, c).

been victimized by one of the fraudulent dealers formerly alluded to by Mr. Nesbit, and had purchased as guano a mechanical mixture of lime and clay; and on applying locally for information, this proved to be the fact.

D. Fair *oats* gave reaction in $\text{H}\ddot{\text{B}}$ much as the above (A), but showed—by the obstinate insolubility of the white opaque balls after addition of potassic carbonate—that magnesian phosphate was present in them.

E. *Barley* grains afforded much the same results, with indications of a large quantity of nitrogen.

Iron oxide was detected in all the above except (B), by the yellow color of some balls while hot in $\text{H}\ddot{\text{B}}$.*

F. The *pericarp of a poppy* from a wheat-field afforded in $\text{H}\ddot{\text{B}}$ an immense quantity of *soluble silica* (watery opalescence), and several opaque white balls of calcic phosphate.

G. A *young potato apple* betrayed, when thus treated, the presence of a large proportion of free phosphoric acid.

H. Some *poppy seeds* also gave a quantity of free $\text{H}\ddot{\text{P}}$ with little SiO_2 .

J. *Shepherd's-purse* showed two large and one small semiopaque balls, with a little free soluble silica, and little or no free $\text{H}\ddot{\text{P}}$.

(269). HEXAGONAL ATOMS.

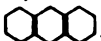
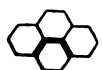
Although the Science of Pyrology is far from being sufficiently prepared by empirical† illustration to admit of the complete application to it of the atomic theory, two or three quantitative experiments as that of the 1 : 3 ratio, in which caustic lime apparently combines under O.P., with $\text{H}\ddot{\text{B}}$, to form a ball of anhydrous calcic borate, seem to show that such an application is, in some cases at least, practicable, and I have ventured to flatter myself that sufficient interest in this almost unopened branch of chemistry will now be awakened in the minds of scientific Englishmen, to induce them to give it a modicum of that attention they have so long, and with such brilliant results, bestowed upon other branches of natural philosophy. I have therefore, in this place, attempted a brief exposition of atomicity, as it is now applied in hydracid chemistry, although, as Dr. Daubeny said long ago,‡ “it is but too true that chemists have often yielded to the temptation of *adapting* the results of their experiments to the standard set forth by the theory of definite proportions, and that the operations of *trimming* and *cooking*, so facetiously explained by Mr. Babbage, in his ‘Essay on the Decline of Science,’ are not altogether confined to astronomers.”

* *Vide* Paragraph (260, d).

† The manner in which the word “Empiric” (*Εμπειρικός* an experimenter), has been corrupted in the English language by designing pedants so as to signify a “quack,” would be amusing if it were not disgraceful. It is impossible to conceive any trustworthy terrestrial science which is not wholly and solely founded on experiment.


‡ ‘The Atomic Theory,’ p. 62, by Charles Daubeny, M.D., F.R.S. Murray. 1831.


(a). It is obvious that if we allow the definitive existence of atoms, and a proportionate weight to each *kind* of atom, we must also allow to each a comparative *bulk*; * a fact, indeed, well illustrated in one of Faraday's lectures by a diagram of the oxides of nitrogen. It seems almost a postulate to such assumptions to assume that these hypothetical atoms have also a definite *shape*, and as the highest atomicity † in terms of an atom of hydrogen ($= 1 \cdot$) belonging to any element, is, according to the chemists, six, it would appear that the *regular hexagon* is the most convenient atomic shape for purposes of graphic representation, which is, as Dalton has himself shown, by far the best method of comprehending, if not of applying, the principles of his theory. This hypothetical atomic shape, however, which is adopted solely for convenience, must not be confounded with the profound investigations and learned dissertations of chemists and mathematicians as to the *real* shape of atoms, which has formed in England a subject of eager inquiry, ever since the Bakerian lecture of Dr. Wollaston, in 1813.

(b). Dr. Frankland has suggested the name of *bonds* for the capabilities of an elementary atom to fix itself or attach other atoms, and the *number* of these bonds is taken as the measure of those capabilities, or, in other words, of its atomicity. Dr. Odling has suggested dashes and Roman numerals above and to the right of the symbol, to represent the number of bonds which an elementary atom can put into force, thus: H^I , Zn^{II} , Au^{III} , C^{IV} , N^V , S^VI . The same thing is expressed in hexagonal atoms, by a *double* line at the point of combination, *inside* the atom, the enclosed space representing the bond, thus: $Zn^{II}Cl^I$, . Here the "diad" zinc, in the centre, has each of its two bonds engaged with one of the "monad" chlorine on either side, the result being a molecule of chloride of zinc, in which four bonds altogether are engaged in three atoms. Auric chloride, or the combination of a single triad atom with three monad atoms, is thus represented: . There is no necessity here to explain to an ordinarily intelligent learner which of the four atoms represented is that of gold, for there is in the figure evidently only one triad atom engaged with three monad ones, or four atoms altogether, with six engaged bonds. The context of the work would, of course, in any case show what must be the nature of the single central triad, and the three monad atoms, and the necessity of printing a chemical symbol in



* Dr. Daubeny says (page 58) that "the comparative *size* of the atoms of bodies may perhaps be calculated from their atomic weight divided by their specific gravity, if we take for granted that every kind of matter possesses in an equal degree the force of gravitation in proportion to its density." According to the "law" of Ampère, all *molecules* are of the same size.


† "Atomicity" may apparently be defined as the capability of an element or compound radical to fix its own atoms, or replace those of another.

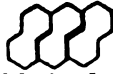

each space, or of filling up or coloring in, that, as Dalton did with his circular atoms, is thus avoided; so that if these hexagons are made small enough, any number of chemical equations may be graphically represented of the size of ordinary type. A case of the combination of a tetrad with four monads, as *marsh gas*, is thus graphically represented: . In this figure an atom of


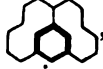
carbon, the centre of the group, has its four bonds engaged with four monad atoms of hydrogen. An instance of a pentad engaged in like manner with five monads is afforded by *ammonic chloride*: . Here nitrogen is, of course,


the central atom, the five bonds of which are represented as holding one chlorine and four hydrogen monad atoms. Finally, a good graphic illustration of a hexad (as sulphur) with its six bonds engaged, is given us by the substance



called *sulphuric anhydride*,  or , where the central atom, sul-

phur, has six bonds, combining it with three *double* atoms of the diad oxygen. The last figure shows us a double atom or diad (oxygen) in combination, and as an atom has no separate existence, such a separate particle is called a "monatomic molecule," its two bonds being said to "satisfy each other." Some elementary monatomic molecules can only exist separately in a double state, as, e.g. H_2 , Cl_2 . These may be thus represented: . *Ozone*, or three of the diad


oxygen atoms, united by six bonds, may be thus represented: , or, more concisely, thus: . A similar figure to the last, but with its bonds very



differently arranged, represents sulphuretted hydrogen, or *hydric sulphide*: , in which an atom of the hexad sulphur holds two of the monad hydrogen. In a molecule of *sulphurous anhydride*, or the pungent smelling gas so easily recognized when sulphur is ignited, we find the sulphur hexad employing only four of its six bonds to hold two diad atoms of oxygen: , and this figure

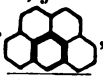
may be compared with the similar one of marsh gas above given, which evidently contains two bonds less. A hexagonal diagram of ammonic chloride has been given above; let us compare with it one of the *gas ammonia* , which is

precisely the same as the figure of auric chloride, but containing two bonds more. An abnormal, or at least remarkable, case, is that of *nitrous oxide* ("laughing gas"), in which two atoms of the pentad nitrogen are held by one of the diad oxygen, , or . Here we find three atoms held together by


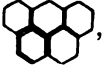

four bonds, while no less than eight bonds are what is called "latent," that is, doing nothing, and as these latent bonds are disengaged in pairs, Dr. Frankland has suggested that they are "satisfying one another," something in the manner of the old story: "What are you doing, John?"—"Nothing, sir." "What are *you* doing Thomas?"—"Helping John, sir." A remarkable instance of this latent satisfaction is given by the pentad element *phosphorus*, the atomic weight of which is only 31, but nothing less than four times this, or 124 (the molecular

weight), can be separated, P_4 , therefore, or  represents the phosphoric molecule, in which four pentads are combined by only six bonds, though, of course, the same figure may be made to show all twenty bonds in combination with, or "satisfaction" of each other, so that half being neutralized, ten bonds

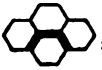
are employed, thus: . *Nitrogen*, another pentad, which in like manner can only be separated molecularly as a double atom (N_2), may be thus shown: .

(c). *Compound Radicals*.—Some compound substances have the curious property of being transferable intact in the manipulations of hydracid chemistry, from one compound to another, just as if they were elements. The hypothetical metal ammonium (NH_4)₂ or , which is a monad, is the best known of

these: it is doubled by *one* line drawn underneath, in order to represent the separable molecule (NH_4)₂, which it would be inconvenient to represent by ten instead of five hexagonal atoms; two lines treble the molecule, three quadruple it, and so on. A similar figure, but with very different bars, would represent


Calcic hydrate, CaH_2O_2 , .† *Hydric nitrate*, HNO_3 , may be thus represented: , and *Hydric sulphate* thus: . In all these figures a little

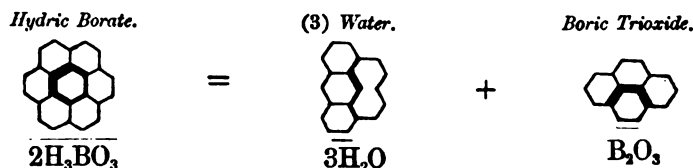
consideration will soon show the student the nature of the atom possessing the highest atomicity, from a knowledge of which that of the others may be easily concluded.

(d). *Molecular Equations*.—As an instance of the hexago-graphic representation of these, let us take the modern chemical account* of the (pyrologically) all-important substance, boric acid, as a subject of illustration. "Boron forms only one combination with oxygen, boric trioxide or anhydride , corre-

* 'Wilson's Inorganic Chemistry,' p. 328. By H. G. Madan, M.A. Oxon. London: Chambers. 1871.

† From this figure the learner sees that calcium is a "diad."

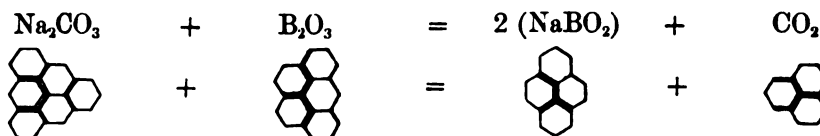
sponding in composition to phosphorous anhydride . [The reader of this article, so far, will have no difficulty in concluding that these figures represent, respectively (B₂O₃) and (P₂O₃), and *also* the atomicity of the constituents.] It is prepared by strongly heating hydric borate, which melts, gives off water, and leaves a transparent, colorless, glassy mass, consisting of the trioxide," thus:



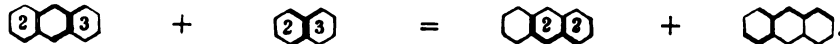
By contracting the figures, and using Arabic numerals inside the hexagons, the equation may be thus concisely illustrated:



Sufficient proof, however, has been brought forward in the course of this work to render it a seemingly safe conclusion that all water is not, in reality, eliminated from these fluxes by simple heat, however violent. Again, according to chemists, "anhydrous" borax is formed from sodic carbonate and boric "anhydride," as follows:



or, more concisely, thus:



It will be observed that the "anhydrous" borax in the above equation is supposed to be a metaborate of sodium.

(e). The following appears to be an approximation of the combining proportion of lime with boric acid:

- (1) 5.6 mgrs. of pure calcined lime gave an $\text{H}\ddot{\text{B}}$ ball weighing 18.5 mgrs.
= 25 per cent. CaO.
- (2) 8 mgrs. of pure calcined lime gave an $\text{H}\ddot{\text{B}}$ ball weighing 33.5 mgrs.
= 23 per cent. CaO.
- (3) 3 mgrs. of pure calcined lime gave an $\text{H}\ddot{\text{B}}$ ball weighing 12.5 mgrs.
= 24 per cent. CaO.

- (4) 7· mgrs. of pure calcined lime gave an $\text{H}\ddot{\text{B}}$ ball weighing 29·5 mgrs.
= 23·5 per cent. CaO.
- (5) 4· mgrs. of pure calcined lime gave an $\text{H}\ddot{\text{B}}$ ball weighing 15·5 mgrs.
= 25·5 per cent. CaO.
- (6) 5·5 mgrs. of pure calcined lime gave an $\text{H}\ddot{\text{B}}$ ball weighing 22·5 mgrs.
= 24·4 per cent. CaO.

Average of the six percentages = 24·2 per cent., which leaves 75·8 as the amount of $\text{H}\ddot{\text{B}}$ in the calciboric ball.

If, however, we assume this nearly anhydrous ball to be a calcic metaborate (CaBO_2), we have, according to modern chemistry, atomic weight Ca = 40 + atomic weight B, = 22 + atomic weight O₂ = 32, = 94, total atomic weight. And 94 : 100 :: 40 = 42·5 per cent. of calcium ; and 94 : 100 :: 22 = 23·4 per cent. of boron ; and 94 : 100 :: 32 = 34 per cent. of oxygen.

From this it appears that, as regards at least some substances, the "law" of combining proportions, evolved from hydracid manipulation, does not hold good in pyrology, but, on the contrary, assuming the atomic weight of oxygen to be unalterably 16 under any circumstances, and the percentages in the above ball to be respectively, lime 25, and $\text{H}\ddot{\text{B}}$ 75, we have the equivalence of calcium under such conditions down as low as 9! and that of boron up as high as 21·5.

(f). I recommend to the learner of this subject to have small sheets of hexagons (which have been prepared for me by Mr. Thomas Kell, of Covent Garden) at hand, so that he can cut from them, with a pair of short, fine-pointed scissors, any figures or equations, by means of which he wishes to illustrate his work. Like a bee forming honeycomb-cells, he will thus best "improve each shining hour" (atomically).

ALPHABETICAL TABLE (IX.) OF ELEMENTARY TYPICAL COMBINATIONS.*

1. **ALUMINUM.**—(a) With Oxygen: *Sapphire, Corundum, Diaspore, Gibbsite.*
 (β) With Fluorine: *Cryolite, Chiolite.*
 (γ) „ Sulphuric Acid: *Aluminate, Alunite, Lowigite, Kalinite, Mendosite, Tschermigite, Pickeringite, Apjohnite, Bosjemanite, Halotrichite, Copiapite, Voltaite.*
 (δ) With Phosphoric Acid: *Turquoise, Wavellite, Attacolite, Childrenite, Cirrolite, Peganite, Fischerite, Tavistockite, Augelite, Amblygonite, Lazulite, Callainite, Barrandite, Plumboresinite.*
 (e) With Silicic Acid: *Cyanite, Andalusite, Sillimanite, Staurolite, Orthoclase, Tourmaline, &c.*
 (f) „ Silica and Water: *Pholerite, Meerschaluminate, Allophane, Kaolin, Pyrophyllite.*
 (g) „ Silica and Fluorine: *Topaz, Pycnite.*
 (θ) Aluminates: *Spinel, Hercynite, Gahnite.*
2. **ANTIMONY.**—(a) Metallic: *Native Antimony.* With Oxygen: *Valentinite.*
 (β) With Nickel: *Breithauptite, Ullmannite.*
 (γ) „ Arsenic: *Allemontite.*
 (δ) „ Silver: *Dyscrasite, Proustite, Pyrargyrite.*
 (e) „ Sulphur: *Stibnite.*
 (f) „ Copper: *Bournonite.*
 (g) „ Lead: *Jamesonite, Berthierite, Boulangerite.*
3. **ARSENIC.**—(a) Metallic: *Native Arsenic.*
 (β) With Oxygen: *Arsenolite.*
 (γ) „ Sulphur: *Realgar, Orpiment.*
 (δ) „ Cobalt, Nickel, &c.: *Smaltite, Millerite.*
 (e) As Acid with Base: *Erythrite, Annabergite.*
4. **BARIUM.**—(a) With Sulphuric Acid: *Barite, Barytocelestite, Drealite.*
 (β) With Carbonic Acid: *Witherite, Barytocalcite, Bromlite.*
 (γ) „ Silicic Acid: *Harmotome, Brewsterite.*
 (δ) „ Manganese: *Psilomelane, Braunitz, Hausmannite.*
5. **BISMUTH.**—(a) Metallic: *Native Bismuth.*
 (β) With Tellurium and Selenium: *Tetradymite.*
 (γ) „ Silver: *Chilenite.*
 (δ) „ Sulphur: *Bismuthinite, Karelinite.*
 (e) „ Copper: *Emplectite, Annivite.*
 (f) „ Lead: *Chiviatite, Kobellite.*
 (g) „ Nickel: *Grünanite, Rammelsbergite.*
 (θ) „ Oxygen: *Bismite.*
 (i) „ Carbonic Acid: *Bismuthite.*
 (κ) „ Phosphoric Acid: *Hypochlorite.*
6. **BORON.**—(a) With Water: *Sassoline.*
 (β) With Soda: *Borax.*
 (γ) „ Ammonia: *Larderellite.*
 (δ) „ Magnesia: *Boracite.*
 (e) „ Lime: *Borocalcite, Hydroboracite.*
 (f) „ Silica: *Tourmaline, Azinite, Datholite.*

* By this term is here to be understood a combination either chemical or mechanical.

- 7. CADMIUM.**—(a) With Sulphur: *Greenockite, Sphalerite*.
(β) With Oxygen: *Calamine*.
- 8. CALCIUM.**—(a) With Chlorine: *Tachydrile*.
(β) With Fluorine: *Fluor Spar, Prosopite, Yttrocerite*.
(γ) „ Sulphuric Acid: *Gypsum, Anhydrite, Polyhalite*.
(δ) „ Nitric Acid: *Nitrocalcite*.
(ε) „ Phosphoric Acid: *Apatite, Francolite, Pyromorphite*.
(ζ) „ Carbonic Acid: *Calcite, Aragonite, Dolomite*.
(η) „ Oxalic Acid: *Whewellite*.
(θ) „ Boric Acid: *Hayesine*.
(ι) „ Arsenic Acid: *Pharmacolite, Kühnite*.
(κ) „ Tungstic Acid: *Scheelite*.
(λ) „ Antimonious Acid: *Roméite*.
(μ) „ Columbic Acid: *Pyrochlore*.
(ν) „ Titanic Acid: *Perovskite*.
(ξ) „ Silicic Acid: *Wollastonite, Augite, Scapolite, Phreznite*.
- 9. CERIUM, LANTHANUM, DIDYMIUM.**—(a) With Fluorine: *Fluocerite, Yttrocerite*.
(β) With Phosphoric Acid: *Cryptolite, Monazite*.
(γ) „ Carbonic Acid: *Parisite, Lanthanite*.
(δ) „ Tantallic Acid: *Fergusonite*.
(ε) „ Titanic and Columbic Acid: *Euxenite*.
(ζ) „ Silicic Acid: *Cerite, Allanite, Orthite*.
(η) „ Silicic and Titanic Acid: *Tschevokinite, Mosandrite*.
- 10. CHROMIUM.**—(a) Metallic: In *Meteoric Iron*, sometimes.
(β) With Oxygen and Iron: *Chromite*.
(γ) „ Alumina: *Chrome Ochre, Walschonsköite*.
(δ) „ Lime: *Ouvarovite*.
(ε) „ Potash and Soda: *Fuchsine*.
(ζ) „ Magnesia: *Spinel*.
(η) „ Glucina: *Chrysoberyl*.
(θ) As Chromic Acid: *Vauquelinite, Melanchroite*.
- 11. COBALT.**—(a) With Arsenic and Iron: *Smaltite*.
(β) With Sulphur and Arsenic: *Cobaltite, Jeypoorite, Linnaeite*.
(γ) „ Nickel: *Siegenite, Grünanite*.
(δ) „ Selenium: *Tillerothite*.
(ε) „ Manganese: *Asbolane*.
(ζ) „ Sulphuric Acid: *Bieberite*.
(η) „ Arsenic Acid: *Erythrine*.
- 12. COPPER.**—(a) Metallic: *Native Copper*.
(β) With Arsenic: *Darwinite, Domeykite, Condurrite*.
(γ) „ Selenium: *Berzelianite, Eucairite*.
(δ) „ Sulphur and Iron: *Copper Glance, Erubescite, Chalcopyrite, Boulangerite*.
(ε) „ Zinc, Silver, Mercury, Antimony, &c.: *Tetrahedrite*.
(ζ) „ Bismuth: *Wittichite*.
(η) „ Silver: *Jalpaite, Polybasite*.
(θ) „ Cobalt: *Carollite*.
(ι) „ Antimony, &c.: *Wölchite*.
(κ) „ Lead: *Bourbonite, Alisonite*.
(λ) „ Chlorine: *Atacamite, Percylite*.
(μ) „ Sulphuric Acid: *Cyanosite*.
(ν) „ Phosphoric Acid: *Liebethenite, Trombolite, Turquoise*.

- (f) With Carbonic Acid: *Malachite Chessylite*.
 - (g) „ Arsenic Acid: *Olivenite, Chalcophyllite*.
 - (h) „ Chromic Acid: *Vauquelinite*.
 - (i) „ Vanadic Acid: *Volborthite*.
 - (j) „ Silicic Acid: *Diopase, Chrysocolla, Allophane*.
13. DIDYMIUM.—See 9.
14. ERBIUM.—(a) With Yttria: *Orthite, Gadolinite*.
15. FLUORINE.—(a) With Lime: *Fluor Spar, Aragonite*.
- (b) With Soda: *Cryolite*.
 - (c) „ Lithia: *Amblygonite*.
 - (d) „ Yttria and Ceria: *Yttracrite, Parisite*.
 - (e) „ Magnesia: *Wagnerite, Chondrodite, Humite*.
 - (f) „ Alumina: *Topaz*.
16. GLUCINUM.—(a) With Silica, Lime, and Magnesia: *Phenakite*.
- (b) With Tin and Iron: *Eucrase*.
 - (c) „ Chromium: *Emerald*.
 - (d) „ Yttria: *Gadolinite*.
 - (e) „ Manganese and Sulphur: *Helvine*.
 - (f) „ Soda and Potash: *Leucophane*.
 - (g) „ Alumina: *Chrysoberyl*.
17. GOLD.—(a) Metallic: *Native Gold*.
- (b) With Palladium: *Porpezite*.
 - (c) „ Rhodium: *Rhodium Gold, Mexico*.
 - (d) „ Tellurium: *Sylvanite*.
 - (e) „ Antimony: *Gelberz*.
 - (f) „ Lead, Copper, and Sulphur: *Nagyagite*.
18. Iridium.—(a) With Osmium, Rhodium, &c.: *Iridosmine*.
19. IRON.—(a) Metallic: *Meteorites, Native, with Graphite*.
- (b) With Arsenic: *Mispickel, Scorodite, Pharmacosiderite*.
 - (c) „ Sulphur: *Pyrite, Chalcopyrite, Kyrosite, Copperas*.
 - (d) „ Oxygen: *Magnetite, Hematite, Gothite*.
 - (e) „ Magnesia: *Magnetite, Cronstedtite*.
 - (f) „ Manganese and Zinc: *Franklinite*.
 - (g) „ Chromium: *Chrome Iron*.
 - (h) „ Chlorine: *Kremersite*.
 - (i) „ Phosphoric Acid: *Vivianite, Chüdrenite*.
 - (j) „ Carbonic Acid: *Chalybite, Humboldtite*.
 - (k) „ Boric Acid: *Lagonite*.
 - (l) „ Tungstic Acid: *Wolframite*.
 - (m) „ Titanic Acid: *Ilmenite, Widelophane*.
 - (n) „ Tantalic Acid: *Tantalite*.
 - (o) „ Niobic Acid: *Columbite*.
 - (p) „ Silica: *Garnet (iron), Nontronite, Anthosiderite*.
 - (q) „ Copper: *Chalcopyrite, Boulangerite*.
20. LEAD.—(a) With Tellurium: *Altaite*.
- (b) With Gold and Silver: *Sylvanite, Nagyagite*.
 - (c) „ Selenium: *Clausthalite, Berzelianite*.
 - (d) „ Sulphur: *Galena, Steinmannite, Caledonite*.
 - (e) „ Chlorine: *Mendipite, Matlockite, Percylite*.
 - (f) „ Oxygen: *Plumbic Ochre, Plattnerite*.

- (n) With Phosphoric Acid: *Pyromorphite, Plumboselenite.*
 - (θ) „ Arsenic Acid: *Mimetite, Carmine Spar.*
 - (ι) „ Carbonic Acid: *Cerussite, Tarnowitzite.*
 - (κ) „ Lime: *Plumbocalcite.*
 - (λ) „ Zinc: *Zinc lead spar.*
 - (μ) „ Chromic Acid: *Melanochroite, Vauquelinite.*
 - (ν) „ Vanadic Acid: *Vanadinite, Descloizite.*
 - (ξ) „ Molybdic Acid: *Wulfenite.*
 - (ο) „ Tungstic Acid: *Scheelite.*
 - (τ) „ Antimony: *Jamesonite, Boulangerite, Bleinierite.*
 - (ρ) „ Copper: *Bournonite, Cuproplumbite.*
21. **LITHIUM.**—(α) With Phosphoric Acid: *Amblygonite, Triphylite.*
 (β) With Silica and Alumina: *Spodumen, Petalite.*
 (γ) „ Potash: *Lepidolite.*
 (δ) „ Lime: *Scapolite.*
22. **MAGNESIUM.**—(α) With Chlorine: *Tachydrite.*
 (β) With Sulphur: *Epsomite, Martinsite.*
 (γ) „ Phosphoric Acid: *Wagnerite, Lazulite.*
 (δ) „ Carbonic Acid: *Magnesite, Breunnerite.*
 (ε) „ Boric Acid: *Boracite, Stassfurthite.*
 (ζ) „ Arsenic Acid: *Picropharmacolite, Kuhnite?*
 (η) „ Silica: *Talc, Sepiolite, Tourmaline, Serpentine.*
 (θ) „ Phosphoric Acid: *Sordawalite.*
 (ι) „ Fluorine: *Chondrodite.*
 (κ) „ Alumina: *Spinel, Piemonte.*
23. **MANGANESE.**—(α) With Arsenic: *Kaninite.*
 (β) With Sulphur: *Alabandine, Hauerite.*
 (γ) „ Oxygen: *Pyrolusite, Psilomelane, Hausmanite.*
 (δ) „ Carbonic Acid: *Diallogite, Manganocalcite.*
 (ε) „ Tungstic Acid: *Wolframite.*
 (ζ) „ Tantalum and Niobic Acid: *Tantalite, Columbite.*
 (η) „ Silica, Alumina, Glucina, &c.: *Rhodonite, Helvine, Carpholite.*
 (θ) „ Zinc and Iron: *Franklinite.*
24. **MERCURY.**—(α) With Selenium: *Onofrite.*
 (β) With Sulphur: *Cinnabar, Hepatic Cinnabar.*
 (γ) „ Copper and Silver: *Spaniolite.*
 (δ) „ Chlorine: *Calomel (Bavaria).*
 (ε) „ Iodine: *Coccinite.*
25. **MOLYBDENUM.**—(α) With Sulphur: *Molybdenite.*
 (β) With Oxygen: *Molybdine.*
 (γ) „ Lead: *Wulfenite.*
26. **NICKEL.**—(α) With Antimony: *Breithauptite.*
 (β) With Arsenic: *Copper Nickel, Chloanthite.*
 (γ) „ Sulphur: *Millerite.*
 (δ) „ Bismuth: *Grünauite.*
 (ε) „ Iron: *Iron Nickel Pyrites.*
 (ζ) „ Cobalt and Copper: *Smaltine, Cobaltine.*
 (η) „ Oxygen: *Pimelite.*
 (θ) „ Carbonic Acid: *Emerald Nickel.*
 (ι) „ Silica, Magnesia, and Iron: *Chrysotile, Röttelite.*

27. NIOBIUM.—(a) With Iron, Manganese, and Tantalio Acid: *Columbite*.

28. OSMIUM.—(a) With Iridium, Rhodium, &c.: *Iridosmine*.

29. PLATINUM.—(a) With Iridium and Copper: *Platiniridium*.

30. POTASSIUM.—(a) With Chlorine: *Sylvine*, *Carnallite*.

(β) With Sulphuric Acid: *Alunite*, *Polyhalite*, *Voltaite*.

(γ) „ Nitric Acid: *Nitre*.

(δ) „ Silica: *Orthoclase*, *Hyalophane*, *Mica*, *Apophyllite*.

(ε) „ Manganese: *Gigantolite*, *Psilomelane*.

(ζ) „ Magnesia: *Villarsite*, *Obsidian*, *Pumice stone*.

(η) „ Lime: *Stilbite*, *Palagonite*, *Apophyllite*.

(θ) „ Soda: *Albite*, *Eudialite*, *Lava*.

31. RHODIUM.—(a) With Iridium, Osmium, &c.: *Iridosmine*.

32. SELENIUM.—(a) With Lead: *Chnusthalite*, *Berzelianite*.

(β) With Mercury: *Onofrite*.

(γ) „ Tellurium: *Tetradymite*.

33. SILVER.—(a) With Gold: *Native Gold*.

(β) With Bismuth: *Bismuth Silver*.

(γ) „ Mercury: *Native Amalgam*.

(δ) „ Antimony: *Pyrargyrite*, *Diserasite*, *Stephanite*.

(ε) „ Tellurium: *Nagyagite*, *Syloanite*.

(ζ) „ Selenium: *Ecuirite*.

(η) „ Sulphur: *Argentite*.

(θ) „ Bromine and Iodine: *Bromyrite*, *Iodyrite*.

(ι) „ Chlorine: *Kerargyrite*.

(κ) „ Arsenic: *Proustite*.

34. SODIUM.—(a) With Chlorine: *Common Salt*, *Sodalite*, *Eudialite*.

(β) With Fluorine and Alumina: *Cryolite*, *Soda*, *Alum*, *Chiolite*.

(γ) „ Sulphuric Acid: *Glauber Salt*, *Thenardite*.

(δ) „ Lime: *Glauberite*, *Analcime*, *Gay-Lussite*, *Natrolite*.

(ε) „ Nitric Acid: *Nitratine*.

(ζ) „ Carbonic Acid: *Natron*, *Cancrinite*.

(η) „ Boric Acid: *Borax*, *Hayesine*.

(θ) „ Silica, Iron, &c.: *Albite*, *Achmite*, *Arfvedsonite*.

35. STRONTIUM.—(a) With Sulphur: *Celestine*.

(β) With Carbonic Acid: *Strontianite*.

(γ) „ Silica: *Brewsterite*.

36. TANTALUM COLUMBIUM.—(a) With Iron: *Tantalite*, *Wolframite*, *Columbite*.

(β) With Lime: *Pyrochlore*.

(γ) „ Yttria: *Yttrotantalite*, *Lamarshite*, *Fergusonite*.

(δ) „ Zirconia: *Wöhlerite*, *Eukolite*.

37. TELLURIUM.—(a) With Gold and Silver: *Sylvanite*, *Nagyagite*.

(β) With Lead: *Altaite*.

38. THORIUM.—(a) With Lime: *Pyrochlore*.

(β) With Yttria: *Lamarshite*.

(γ) „ Silica: *Thorite*, *Orangite*.

- 39. TIN.**—(a) With Sulphur: *Stannite*.
 (β) With Oxygen: *Cassiterite*.
- 40. TITANIUM.**—(a) With Oxygen: *Rutile, Brookite, Anatase*.
 (β) With Lime: *Schorlomite, Sphene, Perowskite*.
 (γ) „ **Yttria**: *Polycrase, Euxenite, Ytrotitanite*.
 (δ) „ **Zirconia**: *Erstedite*.
 (ε) „ **Ceria, &c.**: *Mosandrite, Tschewokinite*.
 (ζ) „ **Iron**: *Ilmenite, Iserine*.
- 41. TUNGSTEN.**—(a) With Oxygen: *Wolframite*.
 (β) With Lime: *Scheelite*.
 (γ) „ **Lead**: *Scheelite*.
 (δ) „ **Iron**: *Wolframite*.
 (ε) „ **Yttria**: *Lamarshite, Yttrotantalite*.
 (ζ) „ **Tantalum and Niobic Acid**: *Columbite, Tantalite*.
- 42. URANIUM.**—(a) With Sulphuric Acid: *Trippite, Johannite*.
 (β) With Iron, Silica, Lime, Lead, &c.: *Pitchblende*.
 (γ) „ **Phosphoric Acid**: *Uranite*.
 (δ) „ **Carbonic Acid**: *Liebigite, Voglite*.
 (ε) „ **Silica**: *Uranophane*.
- 43. VANADIUM.**—(a) With Lead: *Vanadinite*.
- 44. YTTRIUM.**—(a) With Silica and Iron: *Gadolinite*.
- 45. ZINC.**—(a) With Sulphur: *Sphalerite, Przibram Galena*.
 (β) With Manganese and Iron: *Franklinite*.
 (γ) „ **Carbonic Acid**: *Calamine, Aurichalcite*.
 (δ) „ **Silica**: *Smithsonite*.
- 46. ZIRCONIUM.**—(a) With Silica: *Zircon*.

[The analyst may use this Table (at least) in two ways. He may form a typical mineral cabinet from it, in conjunction with the Tables given in pages 194, 198, of this work, for which purpose I can honestly recommend the establishment of Mr. Gregory, the mineralogist, of No. 88, Charlotte Street, Fitzroy Square; or he may analyze any of the minerals given, with the view of detecting the typical elements here indicated.]

TABLE (X.) OF THE COMMONER COLORS OF SOME MINERALS.

	Werner and Jannet.	Animal Kingdom.	Vegetable Kingdom.	Arithmetical Expression.
1 <i>Apatite</i>	Rose Red ..	Flamingo ..	Garden Rose ..	..3
2 <i>Amethyst</i>	Violet Purple ..	..	Purple Aster ..	..6
3 <i>Asbolane</i>	Bluish Black ..	..	Crowberry ..	M 5 + 1
4 <i>Argonite</i>	Purplish White ..	Largest Black Slug ..	White Gernium ..	20..9
5 <i>Azinite</i>	Clove Brown ..	Neck of Kittiwake Gull ..	Stems of Black Currant ..	012..3
6 <i>Brite</i>	Flesh Red (?) ..	Human Skin ..	Larkspur ..	..2 + 20
7 <i>Basalt</i>	Greish Black ..	Breast of Water Ouzel ..	Horse-shoe Geranium ..	Δ 3.75
8 <i>Leryl</i>	Asparagus Green ..	Brimstone Butterfly ..	Nonpareil Apple ..	18.4
9 "	Oil Green ..	Shell of Water Snail ..	Dead Leaves ..	Z 15.2 + 2..1
10 <i>Blende</i>	Deep Reddish Brown ..	Neck of Teal (Drake) ..	..	2..1 + 1
11 "	Yellowish Brown ..	Breast of Hoopoe ..	..	2..1 + 2
12 <i>Calamine</i>	Straw Yellow ..	Polar Bear ..	Oat Straw ..	Δ 18.7 + 2..1
13 <i>Calc Sinter</i>	Greenish White ..	Vent-coverts of G. C. Wren ..	Polyanthus Narcissus ..	20 + 1.5
14 <i>Carrara Marble</i>	Snow White ..	Breast of the Gull ..	Snowdrop ..	20.
15 <i>Ceylanite</i>	Duck Green ..	Neck of Mallard ..	Yew Leaves ..	1.7 + M 1.6
16 <i>Chalcocylony</i>	Yellowish Grey ..	Vent-coverts of White-rump ..	Stems of the Barberry ..	10.2 + 2
17 <i>Chalk</i>	Yellowish White ..	Egret ..	Hawthorn Blossom ..	20 + 2
18 <i>Chessylite</i>	China Blue ..	Rhynchites Nitens ..	Back part of Gentian Flower ..	1 + M 1.6
19 <i>Chrysolite</i>	Pistachio Green ..	Neck of Elder Drake ..	Hymnum-like Saxifrage ..	1.6 + 2..1
20 <i>Cinnabar</i>	Scarlet Red ..	Red Coral ..	Red Oriental Poppy ..	3 + ..1
21 "	Vermilion Red ..	Red Coral ..	Love Apple ..	3 + 2..1
22 <i>Clay Slate</i>	Greenish Grey ..	Quill-feathers of Robin ..	Bark of Ash-tree ..	10.2 + 1.5
23 <i>Egyptian Jasper</i>	Chestnut Brown ..	Breast of Red Grouse ..	Chestnuts ..	2..1
24 <i>Epidote</i>	Olive Green ..	..	Lignum Vitæ ..	3.9
25 <i>Erubescite</i>	Scottish Blue ..	Throat of Blue Titmouse ..	Stamen of Purple Anemone ..	Δ 4..6
26 "	Prussian Blue ..	Wing Spot of Mallard ..	Stamen of Blue Anemone ..	M 1.5 + M 1.6
27 "	Indigo Blue ..	..	..	M 1.6
28 "	Azure Blue ..	Breast of Green Cr. Manakin ..	Grape-hyacinth Gentian ..	..8
29 "	Flax-flower Blue ..	Wings of Devil's Butterfly ..	Flower of Flax ..	1 + 1..8
30 <i>Erythrine</i>	Peacii-blossom Red ..	..	Peach Blossom ..	20..2
31 <i>Flint</i>	Ash Grey ..	Breast of long-tail Titmouse ..	Fresh Wood Ashes ..	Z 13.5
32 "	Smoke Grey ..	Grey part, Breast of Robin ..	..	010.2
33 "	Blackish Grey ..	Back of Nuthatch ..	Old stems of Hawthorn ..	K 7.
34 <i>Fluor</i>	Pansy Purple ..	Chrysomela Goeetingensis ..	Sweet-scented Violet ..	..8 + M 5
35 "	Campanula Purple ..	..	Canterbury Bell ..	..7
36 "	Imperial Purple ..	Egg of largest Bluebottle Fly ..	Parts of Saffron Crocus ..	..6
37 "	Auricula Purple ..	..	Purple Auricula ..	..5 + M 1.6
38 "	Plum Purple ..	Gallstones ..	Plum ..	2..9
39 "	Honey Yellow ..	Breast of Screech Owl ..	Marigold Apple ..	4..1
40 <i>French Chalk</i>	Orange-colored White ..	..	Large Wild Convolvulus ..	20 + 2.5
41 <i>Garnet</i>	Crimson Red ..	..	..	..1
42 "	Purplish Red ..	Outside of quills of Terico ..	Official Garden Rose ..	3 + 2..9
43 <i>Granular Limestone</i>	Greyish White ..	Inside quill-feathers of Gull ..	White Hamburgh Grapes ..	20 + 16.
44 <i>Hepatic Cinnabar</i>	Cochineal Red ..	Coccus Cacti ..	Decayed Leaf of "Nono-so-pretty" ..	010..7

45 Hornblende ..	Greenish Black ..	Breast of Lapwing ..	Red on the Golden Reunet ..	M 5 + 1.5
46 Hymenocallis ..	Hyaline ..	Spots of Lycaeus Apteris ..	Small Fennel Flower ..	2.5 + 2.1
47 Iron Earth ..	Greyish Blue ..	Back of Blue Titmouse ..	..	1 + 16.7
48 Iron Flint ..	Brownish Red ..	Red on Red-throated Diver ..	..	Π 5.1
49 " ..	Umber Brown ..	Moor Buzzard ..	..	2.1 + M 5
50 Jasper ..	Lavender Purple ..	Under-spots, Peacock Butterfly ..	..	..5 + 12.3
51 " ..	Pale Bluish Purple ..	..	..	..5 + K 9.1
52 " ..	Tile Red ..	Breast of Cock Bullfinch ..	..	2.5 + Δ 18.8
53 " ..	Ochre Yellow ..	Vent-coverts of Redstart ..	..	2 + 22.1
54 " ..	Cream Yellow ..	Breast of Teal (Drake) ..	..	Π 4.6
55 " ..	Orange-colored Brown ..	Wing-coverts of Sheldrake ..	..	..2 + K 9.1
56 Kermesite ..	Brownish Purple Red ..	..	..	1.8
57 Lapis Lazuli ..	Ultramarine Blue ..	Wings of Heath Butterfly ..	..	1.2
58 Lenticular Ore ..	Venditter Blue ..	..	..	..
(Limonite)	..	..	..	..
59 Lepidolite ..	Bluish Lilac Purple ..	Lebellula Depressa (Male) ..	Blue Lilac ..	Γ 20.8
60 " ..	Red Lilac Purple ..	Spots, Peacock Butterfly ..	Purple Primrose ..	Γ 20.7
61 Lievrite ..	Brownish Black ..	Wing-coverts of Black Cock ..	..	M 5 + 2.1
62 Lias Limestone ..	Bluish Grey ..	Tail-coverts of Wood Pigeon ..	..	Z 13.5 + 1
63 Mineral Tar (Petroleum) ..	Blackish Brown ..	Stormy Petrel ..	..	Π 2. + M 5
64 Mountain Wood ..	Wood Brown ..	Common Weasel ..	Hazel Nuts (?) ..	Π Z 17.6
..
65 Natrolite ..	Buff Orange ..	Streak on eye of Kingfisher ..	Stamen of White Cistus ..	2.2 + Π 2.1
66 Obsidian ..	Velvet Black ..	Mole ..	Black of Indian Sweet Pea ..	M 5
67 Olivine ..	Reddish Black ..	Breast of Pochard Duck ..	Berry, Fuschia Coccinea ..	M 5 + Π 2.3
68 " ..	Ink Black ..	..	Berry, Deadly Nightshade ..	M 5 + M 1.6
69 Opal ..	Bluish White ..	White of human eyeballs ..	Petals, Blue Hepatica ..	Γ 20 + 1
70 Orpiment ..	Lemon Yellow ..	Large Wasp or Hornet ..	Shrubby Goldlocks ..	2.5
71 " ..	Dutch Orange ..	Golden-crested Wren ..	Common Marigold ..	..1 + Γ 20
72 " ..	Aurora Red ..	Vent-coverts of Pied Woodpecker ..	Red on the Apple ..	Z 13.5 + .8
73 Porcelain Jasper ..	Pearl Grey ..	Back of Kittiwake ..	Petals, Purple Hepatica ..	Γ 20 + 3
74 Porcelain Spar ..	Reddish White ..	Egg of Grey Linnet ..	Back of Christmas Rose ..	..1
75 Pyrope ..	Vinous Blood Red ..	Vinous Blood ..	Dark Purple Scabious ..	..2
76 Ruby Oriental ..	Carmine Red ..	Cochineal ..	Raspberry ..	..3
77 Ruby Spinel ..	Lake Red ..	..	Hepatica ..	1
78 Sapphire ..	Berlin Blue ..	Wing-feathers of Jay ..	Nouparel Apple ..	Π 4.1 + Z 13.5
79 Semi-Opal ..	Wax Yellow ..	Larva of large Water Beetle ..	..	Π 2.1 + M 2
80 " ..	Liver Brown ..	Wing-coverts of Grosbeak ..	..	1.9
81 Sulphur ..	Sulphur Yellow ..	Yellow parts of large Dragonfly ..	Vari-colored Snapdragon ..	2
82 " ..	Primrose Yellow ..	Pale Canary Bird ..	Wild Primrose ..	Π 4.6
83 " ..	Gamboge Yellow ..	Wings of Goldfinch ..	Yellow Jasmine ..	Δ 18.6
84 Topaz ..	Brownish Orange ..	Eyes of large Flesh Fly ..	Style of Orange Lily ..	Γ 22 + Π 4.1
85 " ..	Wine Yellow ..	Body of Silk Moth ..	White Currants ..	1.1
86 " ..	Sienna Yellow ..	Tail, Bird of Paradise ..	Stamen, Honeysuckle ..	1.5 + Γ 22
87 Turquoise ..	Greenish Blue ..	Indian Roller ..	Great Fennel Flower ..	1.6
88 Uranite ..	Slakin Green ..	..	Ripe Coalmar Pear ..	Z 15.6
89 " ..	Grass Green ..	Scarabeus Nobilis ..	Fresh Grass ..	..
90 Wood Tin ..	Hair Brown ..	Head of Pintail Duck ..	Bark of Elm-tree ..	Z 15.6 + 3
91 Zircon (?) ..	Broccoli Brown ..	Head of Black-headed Gull ..	..	..

WERNER'S AND JAMESON'S DESCRIPTION OF COLORS MENTIONED IN THE
ABOVE TABLE.

- 1 *Rose Red* is carmine red with a great quantity of snow white, and a very small portion of cochineal red.
- 2 *Violet Purple* is Berlin blue mixed with red, and a little brown.
- 3 *Bluish Black* is velvet black, mixed with a little blue and blackish grey.
- 4 *Purplish White* is snow white with the slightest tinge of crimson red and Berlin blue; and a very minute portion of ash grey.
- 5 *Clove Brown* is ash grey mixed with a little blue, red, and chestnut brown.
- 6 *Flesh Red* is rose red mixed with tile red, and a little white.
- 7 *Greyish Black* is composed of velvet black with a portion of ash grey.
- 8 *Asparagus Green* is pistachio green, mixed with much greyish white.
- 9 *Oil Green* is emerald green mixed with lemon yellow, chestnut brown, and yellowish grey.
- 10 *Deep Reddish Brown* is chestnut brown with a little chocolate red.
- 11 *Yellowish Brown* is chestnut brown mixed with a considerable portion of lemon yellow.
- 12 *Straw Yellow* is sulphur yellow mixed with much greyish white, and a little ochre yellow.
- 13 *Greenish White* is snow white mixed with a very little emerald green and ash grey.
- 14 *Duck Green* is composed of emerald green with a little indigo blue, much gamboge yellow, and a very little carmine.
- 16 *Yellowish Grey* is ash grey mixed with lemon yellow and a minute portion of brown.
- 17 *Yellowish White* is composed of snow white with very little lemon yellow and ash grey.
- 18 *China Blue* is azure blue with a little Prussian blue in it.
- 19 *Pistachio Green* is emerald green mixed with a little lemon yellow, and a small quantity of brown.
- 20 *Scarlet Red* is arterial blood red, with a little gamboge yellow.
- 21 *Vermilion Red* is scarlet red with a minute portion of brownish red.
- 22 *Greenish Grey* is ash grey with a little emerald green, a small portion of black, and a little lemon yellow.
- 23 *Chestnut Brown* is a deep reddish brown and yellowish brown.
- 24 *Olive Green* is grass green mixed with much brown.
- 25 *Scotch Blue* is Berlin blue with a considerable portion of velvet black, a very little grey, and a slight tinge of carmine.
- 26 *Prussian Blue* is Berlin blue with a considerable portion of velvet black, and a small quantity of indigo blue.
- 27 *Indigo Blue* is composed of Berlin blue, a little black, and a small portion of apple green.
- 28 *Azure Blue* is Berlin blue mixed with a little carmine red.
- 29 *Flax-flower Blue* is Berlin blue with a slight tinge of ultramarine.
- 30 *Peach-blossom Red* is lake red mixed with much white.
- 31 *Ash Grey* is composed of snow white with portions of smoke and French grey, and a very little yellowish grey and carmine.
- 32 *Smoke Grey* is ash grey mixed with a little brown.
- 33 *Blackish Grey* is ash grey with a little blue and a portion of black.
- 34 *Pansy Purple* is indigo blue with carmine red, and a slight tinge of raven black.
- 35 *Campanula Purple* is ultramarine and carmine, equal parts of each.
- 36 *Imperial Purple* is azure and indigo blue with carmine red, about equal parts of each.
- 37 *Auricula Purple* is plum purple, with indigo blue and much carmine red.
- 38 *Plum Purple* is Berlin blue with much carmine, very little brown, and an almost imperceptible portion of black.
- 39 *Honey Yellow* is sulphur yellow mixed with chestnut brown.
- 40 *Orange-colored White* is snow white with very little tile red and King's yellow, and a minute portion of ash grey.
- 41 *Crimson Red* is carmine red with a little indigo blue.
- 42 *Purplish Red* is carmine with a little Berlin blue and a small portion of indigo blue.
- 43 *Greyish White* is snow white mixed with a little ash grey.
- 44 *Cochineal Red* is lake red mixed with bluish grey.
- 45 *Greenish Black* is velvet black mixed with a little brown, yellow, and green.
- 46 *Hyacinth Red* is scarlet red with lemon yellow, and a minute portion of brown.
- 47 *Greyish Blue* is Berlin blue, with white, a small quantity of grey, and a hardly perceptible portion of red.
- 48 *Brownish Red* is chocolate red mixed with hyacinth red, and a little chestnut brown.

- 49 *Umber Brown* is chestnut brown with a little blackish brown.
- 50 *Lavender Purple* is composed of blue, red, and a little brown and grey.
- 51 *Pale Bluish Purple* is lavender purple mixed with a little red and black.
- 52 *Tile Red* is hyacinth red mixed with much greyish white and a small portion of scarlet red.
- 53 *Ochre Yellow* is sienna yellow with a little light chestnut brown.
- 54 *Cream Yellow* is ochre yellow mixed with a little white and a very small quantity of Dutch orange.
- 55 *Orange-colored Brown* is chestnut brown with a little reddish brown, and a small quantity of orange brown.
- 56 *Brownish Purple Red* is lake red with brownish black and a small portion of grey.
- 57 *Ultramarine Blue* is a mixture of equal parts of Berlin and azure blue.
- 58 *Verditter Blue* is Berlin blue with a small portion of verdigris green.
- 59 *Bluish Lilac Purple* is bluish purple mixed with white.
- 60 *Red Lilac Purple* is campanula purple with a considerable portion of white and very little carmine.
- 61 *Brownish Black* is velvet black mixed with a little brown and yellow.
- 62 *Bluish Grey* is ash grey mixed with a little blue.
- 63 *Blackish Brown* is composed of chestnut brown and black.
- 64 *Wood Brown* is yellowish brown mixed with ash grey.
- 65 *Buff Orange* is sienna yellow with a little Dutch orange.
- 66 *Velvet Black* is the color of black velvet.
- 67 *Reddish Black* is velvet black mixed with a very little carmine, and a small portion of chestnut brown.
- 68 *Ink Black* is velvet black with a little indigo blue in it.
- 69 *Bluish White* is snow white mixed with a little Berlin blue and ash grey.
- 70 *Lemon Yellow* is a mixture of gamboge yellow and a little ash grey (the pure yellow of Werner).
- 71 *Dutch Orange* is gamboge yellow mixed with carmine red.
- 72 *Aurora Red* is tile red with a little arterial blood red, and a slight tinge of carmine.
- 73 *Pearl Grey* is ash grey mixed with a little crimson red and blue.
- 74 *Reddish White* is composed of snow white with a very minute portion of crimson red and ash grey.
- 75 *Vinous Blood Red* is carmine red mixed with brownish black.
- 76 *Carmine Red* is lake red with a little arterial blood red.
- 77 *Lake Red* is arterial blood red with a portion of Berlin blue.
- 78 *Berlin Blue* is the pure or characteristic blue of Werner.
- 79 *Wax Yellow* is composed of lemon yellow, reddish brown, and a little ash grey.
- 80 *Liver Brown* is chestnut brown mixed with a little black and olive green.
- 81 *Sulphur Yellow* is lemon yellow mixed with emerald green and white.
- 82 *Primrose Yellow* is gamboge yellow mixed with a little sulphur yellow and much snow white.
- 83 *Gamboge Yellow* is the pure or characteristic color (Jameson).
- 84 *Brownish Orange* is orpiment orange with a little hyacinth red, and very little light chestnut brown.
- 85 *Wine Yellow* is sulphur yellow mixed with reddish brown and grey, with much snow white.
- 86 *Sienna Yellow* is primrose yellow with a little ochre yellow.
- 87 *Greenish Blue* is composed of Berlin blue, white, and a little emerald green.
- 88 *Siskin Green* is emerald green mixed with much lemon yellow and a little yellowish white.
- 89 *Grass Green* is emerald green mixed with a little lemon yellow.
- 90 *Hair Brown* is clove brown mixed with ash grey.
- 91 *Broccoli Brown* is clove brown mixed with ash grey and a small tinge of red.

NOTE.—The above table is an adaptation of the arithmetical expression of Tints and Tones (given at pp. 116, 117) to the exposition of a very useful idea of the celebrated German mineralogist, Werner (whose *éloge* was pronounced by Cuvier), that the color of minerals might be advantageously compared with familiar objects in the two other "kingdoms." This exposition was made by Werner's pupil, Professor Jameson, assisted by the artist, P. Syme, and a second edition published in Edinburgh in 1821. It is illustrated by squares of color, most of which have retained their tint wonderfully during the fifty years which have passed.

From these colored squares, as well as from the directions for mixing the pigments above detailed, I have given their arithmetical expression as practice in using the tables at pp. 116, 117; regarding which, it must be carefully noted that the sign + denotes the addition of a *trace only* of the succeeding color, while the *actual* addition of the figures expressing two or more chromatic tints denotes that the pigments which those represent are to be mixed together in *equal proportions*.

APPENDIX (A).

PLINY'S "CADMIA."

A GREAT preponderance of evidence* seems to show that the "ore of copper" referred to by Pliny, under the name "*Cadmia*," was *Copper Nickel*. In B. XXXIV., Cap. 2, he says, "The metal (copper) is also obtained from a *coppery stone* (à lapide æroso) found in Germany, called *Cadmia*," the metal derived from which he, in many places, calls "white copper," and states that it is "brittle" (not sufficiently de-arsenicized), in contradistinction to the Cyprian copper, which was red and malleable. In B. XXXIII., Cap. 45, he says, "The best mirrors were a composition of stannum and copper," implying, apparently, that the alloy was *perfectly* white, and could not therefore have really contained copper. In B. XXXIV., Cap. 10, he tells us that the sublimate from the ore *Cadmia* (arsenic), "attached to the arched top and sides of the furnace," is used therapeutically, "the better kind being red, friable, and extremely useful as a remedy for affections of the eyes, for the cure of itch, scab, and for making wounds cicatrize." In B. XXXIV., Cap. 55, he states of *Sandarach* (Realgar), that "the redder it is, the more pure and friable, the better it is in quality. It is also employed as an ingredient in *ophthalmic preparations*, is detergent, astringent, most remarkable for its septic properties, and curative of scurf in the hair." Now, in the 'Modern Materia Medica,' by Dr. Garrod, F.R.S., we find arsenic "acts externally as an escharotic, and is employed internally in chronic *skin* affections."†

Collecting the evidence, we have (1) *Cadmia* occurring in nature as a "*coppery stone*"; (2) producing a *white* metal more brittle than copper; (3) which, when combined with *Stannum* (to be presently investigated), forms a white alloy, preferred to silver; and (4) vaporizes under heat, producing a sublimate which (5) is *red* (arsenic sulphide), and (6) has the therapeutical properties of arsenic. I submit that this evidence is almost overwhelming, and has apparently been overlooked by Beckman, Ajasson, and other investigators of the subject, on account of their omission to notice and keep in view the two facts, (*a*) of the copper-colored *ore*, and (*β*) the expression "white copper." Again, in B. XXXIV., Cap. 11, Pliny says of verdigris, which is green, "*pluribus fit ea modis namque et à lapide ex quo coquitur æs, deraditur, et ære candido*," &c. Now, both copper and nickel ores have sometimes a green efflorescence, but nickel is the only *white metal* which has green salts, as copper nickel is the only mineral to which the expression "a coppery stone" could be applied.

* Recorded evidence is here alone referred to.

† Page 62.

Beckman, and after him, Dr. Bostock and Mr. Riley,* having predetermined cadmia to be *Calamine*, the latter gentlemen have not scrupled to mistranslate "Namque ipse lapis ex quo fit aes, cadmia vocatur, fusuris necessarius, medicinæ inutilis," as follows; "For, as the mineral itself, from which it is prepared artificially, so necessary in fusing copper ore, and *so useful* in medicine, has the name of Cadmia, &c."

Now it seems evident that Pliny, who begins this sentence by alluding to the different kinds of copper (*Plura autem genera sunt*), means to say that of these two kinds, there is "the stone itself called cadmia from which (white) copper is made," and another kind "unavoidably fused" as true copper is in the furnace (and not sublimated like cadmia) which is, unlike arsenical sublimate, "*useless* for medicinal purposes," a fact we can easily understand after the above references to realgar, for the Romans seemed to swallow orpiment like sugar, and Pliny describes it as being, when taken with turpentine, "a pleasant remedy for a cold" (!); while nowhere, so far as I can see, is it described as being poisonous, although he calls lead carbonate a deadly poison ("*letalis potus*") just before. It would really seem as though arsenic had acquired some of its poisonous qualities in the long period which has elapsed since the time of Pliny.†

There is some slight probability that "*Stannum*" was zinc, but far from the same amount which induces us to think cadmia was copper nickel. In the first place, all admit that the Romans' "black lead" was our lead, and their "white lead" our tin. Pliny states, under this head of "Black Lead" (B. xxxiv., Cap. 16), that stannum was obtained "*from an ore* which contains it in common with silver." This clear statement seems to dispose of the supposition, so universally entertained, that it was an *alloy* like pewter. He further says, "the metal that first becomes liquid in the furnace is called stannum; the next that melts is silver." Now *Blende* is almost always met with in beds and veins accompanying most of the ores of silver, lead, and copper,‡ so much so, that the Cornish miners, who call the mineral "Black Jack," said also that "Jack rode a good horse."

Again, in B. xxxiii., Cap. 5, under the head of "Soldering," the solder for stannum is stated to be "copper file-dust"; and that for silver to be "stannum." In B. xxxiv., Cap. 17, Pliny says, "Where copper vessels are coated with stannum, they produce a less disagreeable flavour, and the formation of verdigris is prevented; it is also remarkable that the *weight of the vessel is not increased*." Such results as these, allowing for exaggeration on the part of the writer, and the probable defectiveness of our knowledge of his operations, could, as it seems to me, be produced only by zinc.

* See Bohn's 'Pliny,' vol. vi., p. 192.

† Mr. Darwin says ('Origin of Species') that in Pliny's time the *pear* was a most insipid fruit.

‡ Bristow's 'Glossary,' p. 46.

APPENDIX (B).

TABLE I.—COMPORTMENT OF ALKALIES, EARTHS, AND METALLIC

(From Plattner, translated and edited

[About 20 per cent. of fused Sodid Carbonate is added to the Boric Acid bead to obtain the

ALKALIES.		Upon Platinum Wire.	
1. Potassa.	KO	When covered with the point of the blue flame, the outer flame is colored violet. A small addition of Soda prevents this reaction.	
2. Soda.	NaO	The flame is colored yellow, although Potassa is present.	
3. Lithia.	LO	If no Soda be present the flame is reddened.	
4. Ammonia.	NH ¹	0	

EARTHS.		Upon Charcoal, and with Borax, on the Platinum Wire.	
1. Baryta.	BaO	Caustic; infusible. The Hydrate and Carbonate melt, and are absorbed by the charcoal.	The Carbonate decrepitates, and forms a bead, which is transparent when cold.
2. Strontia.	SrO	Hydrate, fusible: the Carbonate only partly so. Reduction flame reddened.	Ditto. [With moist soluble salts, the flame is intensely crimson.]—Ed.
3. Lime.	CaO	Caustic; not changed. The Carbonate becomes caustic, and emits an intense white light.	Readily dissolved. The Carbonate deflagrates, and forms, when cold, a transparent crystalline glass.
4. Magnesia.	MgO	The Carbonate is decomposed, and the residue emits a strong light, and has an alkaline reaction.	Like Lime; but the bead formed is not so crystalline.
5. Alumina.	Al ² O ³	Not changed.	Fuses to a colorless glass, which remains so when cold.
6. Glucina.	Gl ² O ³	Ditto.	Fuses to a colorless glass, which becomes slightly opaque when cold.
7. Yttria.	YO	Ditto.	Behaves like Glucina.
8. Terbia.	TO ³	Ditto.	Behaves like Glucina.
9. Erbia.	EO ³	Assumes a lighter color in the reduction flame.	No striking change.
10. Zirconia.	Zr ² O ³	Infusible, but produces a very glaring white light.	Fuses to a colorless glass, which becomes slightly opaque when cold.
11. Thoria.	ThO	Not changed.	With a minute quantity, forms a clear glass.
12. Silicic Acid.	SiO ²	Ditto.	Gives a transparent and colorless bead, which is soluble.

[The only way that Potassa, if contained in a mixture of Potassa and Soda, can be detected by the platinum wire, and to add the mixture. If Potassa be present, the brown color of

APPENDIX (B).

OXIDES, ALONE AND WITH REAGENTS, IN THE BLOWPIPE FLAME.

by the late Dr. S. Muspratt, of Liverpool.)

reactions of *Borax*, and to the Phosphoric Acid bead to obtain those of *Microcosmic Salt*.]

Upon Platinum Foil.		Remarks.
0		When in solution, they tinge reddened litmus paper blue.
0		
Fuses, with the formation of a dark yellow coating on the surface.		
0		Recognized by its pungent odor. It affects litmus paper in the same manner as the preceding alkalies.
With Microcosmic Salt, upon Platinum Wire.	With Carbonate of Soda, on Charcoal.	With a Solution of Cobalt, in the Oxidating Flame.
As with Borax.	Dissolves, and is absorbed by the charcoal.	Fuses to a yellowish-red globule, which is colorless when cold. Becomes greyish by exposure.
Ditto.	Caustic: insoluble. The Carbonate dissolves, and is absorbed by the charcoal.	Scintillates and partakes of a black or dark grey color.
A colorless bead, which, if saturated, becomes opaque when cold.	Not dissolved. The reagent is absorbed by the charcoal.	Perfectly infusible; becoming grey.
Ditto.	No action.	Assumes, on cooling, a beautiful flesh-red color.
Fuses to a transparent glass, which becomes slightly opaque, if an excess is present.	Intumescent, with the formation of an insoluble compound. The excess of carbonate of soda is absorbed.	Gives a fine transparent blue glass upon cooling.
As with Borax.	No action.	Infusible, but becomes of a bluish grey color.
Like Glucina.	Insoluble.	0
As with Borax.	Ditto.	0
Fuses very slowly; and is scarcely transparent when cold.	No action.	Partakes of a dirty violet color.
As with Borax.	Ditto.	0
Ditto.	Ditto.	With a very small quantity of the cobalt solution, a slight blue color is produced, which changes to a dark grey, when an excess is produced.

blowpipe, is to fuse a clear bead of Borax with a small quantity of Oxalate of Nickel, upon the the Nickel bead is changed to blue: a salt of Soda effects no such change.]—*Editor*.

TABLE II.—COMPORTMENT

METALLIC OXIDES.	Per Se, on Charcoal.		With Borax on Platinum Wire.	
	In the Oxidating Flame.	In the Reducing Flame.	In the Oxidating Flame.	In the Reducing Flame.
1. Sesquioxide of Cerium. Ce_2O_3 .	The Protoxide is converted into the higher oxide. In the reducing flame, this reaction remains unchanged.		Soluble, forming a red or dark yellow glass. When cool, the glass is only yellow.	The glass containing oxide becomes pale, so that a yellow oxide becomes colorless. When a large quantity of the oxide is present, the glass is, on cooling, of an enamel white crystalline texture.
2. Oxide of Lanthanum. LaO .	Unchanged.		Gives an opaline glass.	
3. Oxide of Didymium. DiO .	Unchanged.	Becomes grey, losing its brown color.	Amethyst colored glass.	No change.
4. Sesquioxide of Manganese. Mn_2O_3 .	Infusible. On being slightly heated, it becomes of a brown color. [The Per-, Sesqui-, and Protoxides, produce similar effects.]— <i>Ed.</i>		Intensely colored—violet (amethyst) while hot; violet, with a tinge of red, when cold. If a large quantity is present, the globule will be black.	The pink bead becomes colorless. Should the color be very intense, the reduction will succeed better upon charcoal with the addition of a small quantity of tin.
5. Sesquioxide of Iron. Fe_2O_3 .	No change.	Becomes black and magnetic.	When a small quantity is present, the glass is yellow, while hot, but colorless when cold. If a large quantity is present, it is red when hot, yellow on cooling. When an excess is present it is dark red when hot, dark yellow after cooling.	On platinum wire the glass becomes bottle green. On charcoal with tin, the glass containing the oxide of iron becomes bottle green. On the platinum wire, the glass heated with tin immediately appears copperas green.

OF METALLIC OXIDES.

With Microcosmic Salt on Platinum Wire.		With Carbonate of Soda on Charcoal or Platinum.	With a Solution of Nitrate of Cobalt, in the Oxidating Flame.
In the Oxidating Flame.	In the Reducing Flame.		
As with Borax; but the color disappears entirely when cold.	The glass is colorless when hot and cold; by this reaction it is distinguished from iron. The glass remains also clear when over saturated.	Not fused; soda absorbed by the charcoal, the metal remaining upon the surface of the support, in the state of a white or lightish grey protoxide.	No reaction.
As with Borax.		Insoluble.	0
Ditto.		Insoluble. The soda is absorbed by the charcoal, and the oxide remains, having a grey color.	0
When a large quantity is added, the glass appears violet, but on the addition of more, it acquires a black tinge. If the salt contains much oxide, on being heated strongly, gas is evolved. Saltpetre assists in bringing out the color, when added.	The glass becomes instantly colorless, both on platinum wire and charcoal. After reduction, the glass becomes perfectly fluid.	In the oxidating flame, upon platinum wire or platinum foil, it fuses to a soluble transparent green mass, becoming opaque and bluish-green, on cooling. On charcoal it cannot be reduced.	0
The glass containing a certain quantity becomes yellowish-red. When cooling it appears first yellow, then greenish, and lastly colorless. If a very large portion is present, the color will be dark red while hot, and brownish-red on cooling, changing to dirty green, and, when perfectly cold, brownish-red. The colors disappear on cooling, quicker than with borax.	The glass is not changed from the presence of a minute portion; but if a large quantity is present, it is red when hot, yellow during refrigeration, then greenish, and when quite cold reddish. With the addition of tin, the glass is first green, and then the color is destroyed.	Insoluble. On charcoal it is reduced; and gives, on being pulverized, a grey metallic magnetic powder.	0

TABLE II.—COMPORTMENT OF

METALLIC OXIDES.	Per Se, on Charcoal.		With Borax on Platinum Wire.	
	In the Oxidating Flame.	In the Reducing Flame.	In the Oxidating Flame.	In the Reducing Flame.
6. Oxide of Cobalt. CoO.	<i>No change.</i>		Deep blue while hot and when cold. Should an excess be present, the glass will appear of a blackish hue.	
7. Oxide of Nickel. NiO.	<i>No change.</i>		Strongly colored.—When a small quantity is present, the glass is violet when hot, and pale reddish-brown when cold.	The glass containing the oxide becomes dull or quite opaque, from the presence of finely divided metallic nickel. By long blowing, the particles of nickel adhere to one another, forming a globule or bead, and the flux becomes colorless.
8. Oxide of Zinc. ZnO.	Yellow bead while hot; white when cold. It does not fuse, but when very hot gives out an intense light.	It is gradually dissipated over the charcoal, with white flakes of oxide of zinc.	Very soluble, forming a clear mass, which, if perfectly saturated, remains colorless when cold. By a strong heat it is reduced, acting on the platinum.	The saturated mass will become enamel white upon platinum wire. On charcoal the oxide is reduced, and the zinc volatilized. The charcoal also acquires a coating.
9. Oxide of Cadmium. CdO.	No change upon platinum foil.	Disappears in a short time, covering the charcoal all over with a dark yellow powder, which is only clearly discerned when the mass cools.	When large quantities are present—the borax melts to a clear yellowish glass; this color nearly disappears on cooling. When the borax is nearly saturated, the glass formed is sometimes, here and there, milk-white, and when perfectly saturated, it becomes enamel white, if slowly cooled.	On charcoal the glass containing the oxide of cadmium boils; the cadmium is reduced and volatilizes, and the charcoal becomes coated with dark-brown oxide.
10. Oxide of Lead. PbO.	Minium (red lead) when slightly heated becomes black; but upon increase of temperature it is converted into a yellow oxide.	It is immediately reduced to a metallic globule, which gradually sublimes, leaving a yellow residue.	Readily fuses to a clear yellow glass, colorless when cold. If a large quantity is present, the globule will be here and there opaque. With an excess it is enamel yellow when cold.	The glass diffuses itself over the charcoal, becomes turbid, and boils. The lead is reduced, and the glass becomes again clear. It is very difficult to obtain in the process a bead of lead.

METALLIC OXIDES—*continued*.

With Microcosmic Salt on Platinum Wire.		With Carbonate of Soda on Charcoal or Platinum.	With a Solution of Nitrate of Cobalt, in the Oxidating Flame.
In the Oxidating Flame.	In the Reducing Flame.		
<p>As with Borax, but the color, however, is not so intense.</p> <p>[By transmitted light, the glass appears reddish. If a bright iron wire is inserted into the mass when in fusion, Cobalt is deposited.]—<i>Ed.</i></p>		On platinum wire in small quantities, it affords a transparent slightly red soluble mass, which is grey when cold. It is reduced on charcoal, giving a grey magnetic powder.	0
Melts to a reddish glass, which is yellow on cooling. If more is added, the glass assumes a brownish-red when hot, and a reddish-yellow when cold.	Upon platinum wire, not altered. Treated on charcoal with tin, the glass is, at the commencement, translucent and grey, but by continued blowing, the nickel deposits, leaving the glass colorless.	Insoluble. It is easily reduced upon charcoal, giving small white shining metallic particles, which, on being triturated, are readily attracted by the magnet.	0
Like Borax, but with this difference, that the saturated glass becomes enamel white upon cooling.		Insoluble. Is reduced on charcoal, covering it with a sublimate of oxide. By a strong flame, the metal may be inflamed.	Gives a beautiful green color.
With large quantities it fuses to a transparent glass; if saturated, it becomes milk-white on cooling.	<p>Upon charcoal, cadmium is slowly and imperfectly reduced; the metal is volatilized, and a very small quantity of a dark red oxide coats the support.</p> <p>[This color, when cold, is a beautiful orange-red.]—<i>Ed.</i></p>	Insoluble. On charcoal it is immediately reduced; the metal is converted into vapor, and the charcoal becomes coated with a dark yellow oxide.	0
As with Borax. It is necessary to add a large quantity of the oxide of lead to obtain a decided color when hot.	On charcoal the glass becomes grey and turbid. If an excess be present the charcoal will be coated with a yellow oxide of lead. When tin is added the glass never becomes opaque, but a little more turbid and of a darker grey.	In the oxidating flame, upon platinum wire, it fuses readily to a limpid glass, which, upon cooling, becomes yellow and opaque. On charcoal the oxide is readily reduced.	0

TABLE II.—COMPORTMENT OF

METALLIC OXIDES.	Per Se, on Charcoal.		With Borax on Platinum Wire.	
	In the Oxidating Flame.	In the Reducing Flame.	In the Oxidating Flame.	In the Reducing Flame.
11. Oxide of Bismuth. BiO^3 .	On platinum foil it fuses readily to a dark brown mass, which becomes pale yellow on cooling.	On charcoal it is quickly reduced to grains of bismuth, which, with long blowing, vaporize, leaving the charcoal covered with yellow oxide.	Readily fusible to a limpid glass, which, when a certain quantity is present, is yellow when hot, colorless when cold. A large quantity gives a yellowish-red glass when hot; while cooling it is yellow, and when perfectly cold, opalescent.	On charcoal the glass becomes, at the commencement, grey and turbid; boils; the oxide of bismuth being reduced, it again becomes perfectly clear. With tin added, it is first grey, and then the whole of the bismuth separates, and the glass appears clear and limpid.
12. Sesquioxide of Uranium. U^2O^3 .	It is converted into the protoxide; it blackens, but does not fuse.		As with oxide of iron, but the color is somewhat clearer. When the glass is strongly saturated, it is streaked with enamel yellow.	Gives the same color as oxide of iron. The green glass, when saturated to a certain point, is blackened by an intermitting flame. It is either crystalline or enamel.
13. Oxide of Copper. CuO .	Forms a black globule, which flows over the charcoal, and the under surface is reduced.	By a temperature at which the copper does not fuse, the oxide is reduced, presenting the fine metallic lustre of copper. When the blowing ceases, the surface of the metal is re-oxidized, and becomes black or brown. By increasing the heat, a globule of copper is obtained.	The glass is not very strongly colored. A small proportion of the oxide gives a grass-green when hot, becoming blue on cooling. By a larger dose of the oxide, the glass is intensely green, appearing opaque; on cooling it becomes opaque and greenish-blue.	At a certain point of saturation, the glass becomes colorless; but in a few moments it becomes red and opaque. By long blowing, the copper is precipitated in the metallic state upon charcoal, and the glass becomes colorless. When treated with tin the glass is opaque, and brownish-red on cooling.
14. Oxide of Silver. AgO .	Reduced very rapidly.		Partly reduced and partly dissolved. On cooling, the glass becomes milk-white or opaline, owing to unequal distribution of the dissolved oxide. Metallic silver melts with borax, giving the same reaction.	On charcoal the glass containing the oxide becomes grey on account of the reduced silver. Postcedently, it becomes limpid and colorless from the precipitation of the silver. This metal can be obtained as a bead.

METALLIC OXIDES—continued.

With Microcosmic Salt on Platinum Wire.		With Carbonate of Soda on Charcoal or Platinum.	With a Solution of Nitrate of Cobalt, in the Oxidating Flame.
In the Oxidating Flame.	In the Reducing Flame.		
A small quantity fuses to a transparent glass. If a large quantity is present, the glass will be yellow when hot, but colorless when cold. If a certain quantity is present, an enamel-white here and there is often produced. When an excess is present, enamel-white on cooling.	On charcoal, particularly when tin is added, the glass remains colorless and limpid while hot; but on cooling becomes opaque and greyish-black.	Easily reduced upon charcoal. [When volatilized, it gives no color to the flame, by which means it is distinguished from antimony, tellurium, &c.]— <i>Ed.</i>	0
Dissolves, giving a clear yellow glass, which becomes green on cooling.	The glass containing the oxide partakes of a beautiful green color, which, on cooling, becomes finer and clearer.	Insoluble. With a small addition of soda it gives indications of melting; with a greater quantity of soda, it becomes yellowish-brown; and by a still greater addition, the oxide is absorbed by the charcoal unaltered.	0
The glass containing the same quantity of oxide as with borax is not so highly colored. A small quantity of oxide gives a green glass when hot; blue when cold. A greater quantity gives a beautiful green when hot; blue when cold. An excess of oxide gives an opaque glass when hot; a greenish-blue when cold.	When nearly saturated the glass is of an intensely dark green while hot, and on cooling appears opaque and of a reddish-brown. When the glass containing a very small quantity is treated with tin, it is opaque and reddish-brown when cooled.	It dissolves upon the platinum wire to a limpid green glass, which, by refrigeration, loses its color, becoming opaque. It is readily reduced upon charcoal, and gives one or more beads of copper.	0
Metallic silver, as well as the oxide, gives a yellowish glass. If a large quantity is present, the glass becomes opaline, and appears yellowish by daylight, red by candlelight.	As with borax.	It is instantly reduced.	0

TABLE II.—COMPORTMENT OF

METALLIC OXIDES.	Per Se, on Charcoal.		With Borax on Platinum Wire.	
	In the Oxidating Flame.	In the Reducing Flame.	In the Oxidating Flame.	In the Reducing Flame.
15. Oxide of Mercury. HgO .	Instantly reduced and volatilized. [Should the whole not sublime, foreign matters will have been present, so that by this means adulteration is detected.]— <i>Ed.</i>		As with microcosmic salt.	
16. Peroxide of Platinum. PtO^2 .	Easily reduced: the metallic particles will not adhere to form a globule.		Reduced, but not soluble. The metallic particles alone upon charcoal do not form globules.	
17. Peroxide of Palladium. PdO^2 .			[“These metals have no action upon the fluxes, which can only serve to detect the foreign metals they may be combined with. “They are best examined by cupellation with lead.”]— <i>Ed.</i>	
18. Peroxide of Rhodium. R^2O^3 .				
19. Binoxide of Iridium. IrO^2 .				
20. Oxide of Ruthenium.				
21. Peroxide of Gold. AuO^3 .	The instant the peroxide becomes red hot it is reduced.		It is not soluble, but is reduced, and can, by fusion, be obtained as a metallic globule. [“Gold has no tendency to combine with oxygen or sulphur, and hence retains its brilliancy in the open air for any length of time. It melts at 2016° ; its density is 19.5; it is not acted on by any single acid, but is dissolved by aqua regia, and by a mixture of nitric and hydrofluoric acids.”]— <i>Ed.</i>	
22. Binoxide of Tin. SnO^2 .	The protoxide inflames like touchwood, and is converted into the sesquioxide. The sesquioxide burns brilliantly, but it remains unchanged.	The sesquioxide of tin is reduced by long heating.	In small quantities it dissolves but very slowly, forming a glass which is colorless and limpid, whether hot or cold; it may, perhaps, become opaque. A glass perfectly saturated, when heated, becomes opaque, loses its globular form, and appears a confused crystalline mass.	A glass containing a small quantity of the oxide is not altered. If more be added, the oxide is partly reduced upon charcoal.

METALLIC OXIDES—continued.

With Microcosmic Salt on Platinum Wire.		With Carbonate of Soda on Charcoal or Platinum.	With a Solution of Nitrate of Cobalt, in the Oxidating Flame.
In the Oxidating Flame.	In the Reducing Flame.		
<p>"All the compounds of mercury are volatile; mixed with tin or iron filings and heated in a glass tube, metallic mercury distils over."</p>		<p>When mixed with soda and heated to redness in a closed tube, it is reduced and vaporized. The sublimate condenses in the coldest part of the tube as a grey coating, which, when agitated, unites, forming a globule.</p>	0
As with borax.			0
As with borax.			0
<p>It dissolves in small quantities very slowly, giving a limpid and colorless glass, which is not changed on cooling.</p>	<p>The glass containing the oxide is not altered, either upon platinum wire or charcoal.</p>	<p>Upon the platinum wire peroxide of tin (stannic acid) effervesces, combining with the soda, forming an unmeltable tumacious mass. Upon charcoal it is converted into the metallic state.</p>	<p>Assumes a bluish-green color.</p>

TABLE II.—COMPORTMENT OF

METALLIC OXIDES, AND ACIDS.	On Charcoal, without Reagents.		With Borax on Platinum Wire.	
	In the Oxidating Flame.	In the Reducing Flame.	In the Oxidating Flame.	In the Reducing Flame.
23. Terioxide of Antimony. SbO^2 .	It is displaced without change, and deposited upon another part of the charcoal.	It is reduced, and sublimes. The charcoal becomes coated with a white oxide, and a greenish-blue color is imparted to the flame. [Antimony, when heated in a tube open at both ends, gives off large quantities of white vapors.]—Ed.	It dissolves in large quantities, and gives a limpid glass, which in the flame appears yellow, and on cooling becomes almost colorless. On charcoal, the dissolved oxide becomes paler; an addition of tin does not alter this effect.	The glass, when treated only for a short time in the oxidating flame, becomes grey and cloudy from particles of the reduced antimony; these are quickly volatilized, and the glass becomes lucid. When treated with tin the glass becomes ash-grey or black, whether there is a large or a small proportion of the oxide present.
24. Sesquioxide of Chromium. Cr^2O^3 .	Unchanged.		It colors the borax highly, but it dissolves slowly. If an equal quantity is present, the glass will be yellow when hot, yellowish-green when cold. If a larger quantity is present it is dark red when hot; on cooling, yellow; and when cold, emerald green with a trace of yellow.	The slightly saturated glass is of a beautiful green, when hot or cold. When a greater quantity is added, the color is more strongly marked, becoming emerald green. The addition of tin does not produce any change.
25. Tellurous Acid. TeO^2 .	Melts, and is reduced with effervescence. The reduced metal volatilizes, and covers the charcoal with a coating of white oxide.		Dissolves, forming a limpid colorless glass; heated upon charcoal its color is grey, becoming opaque by reduction from the metallic particles disseminated through the mass.	
26. Molybdic Acid. MoO^3 .	It melts and is absorbed by the charcoal. In a strong reduction-flame, particles of the metal appear which separate in the form of a grey metallic powder.		Soluble, forming a limpid glass, which appears yellow upon cooling, but is colorless when cold. When a large proportion of acid is present, the glass is dark yellow when hot, opaline when cold. With an excess, the glass is dark red when hot, becoming on cooling of an opalescent bluish-grey.	The glass treated in the oxidating flame with a very small quantity of acid, is colored brown. If a little more be added, the glass becomes wholly opaque.
27. Niobic Acid.	Becomes greenish-yellow in the heat; white when cold.		Like tantalic acid.	

METALLIC OXIDES AND ACIDS.

With Microcosmic Salt on Platinum Wire.		With Carbonate of Soda.	With a Solution of Nitrate of Cobalt, in the Oxidating Flame.
In the Oxidating Flame.	In the Reducing Flame.		
Dissolves with effervescence, giving a clear glass, which, when hot, appears of a feeble yellow color.	The saturated glass upon charcoal becomes milky at first, but in a short time clear; the antimony being reduced and dispersed in vapor. When treated with tin the glass is grey; this color is owing to the reduced metal, but it soon becomes clear with strong blowing. The tin produces always a murky-grey color when a very small proportion of the oxide of antimony is present.	Upon charcoal it is very easily reduced. The metal fumes and covers the charcoal with a coating of white oxide.	0
Soluble, forming a limpid glass, which is reddish when hot, and of a dull green color on cooling. When perfectly cold it appears of a beautiful green hue.	As in the oxidating flame. The colorations appear more marked; this is the same under the influence of tin.	In the oxidating flame, upon platinum wire, it is dissolved with the formation of a dark brown yellowish glass, which, upon cooling, becomes yellow and opaque. In the reducing flame the glass is opaque, and green when cold.	0
As with borax.		Soluble on the platinum wire, producing a limpid and colorless glass, which becomes white upon cooling. Upon charcoal it is reduced, volatilizes, and leaves upon the support a coating of oxide.	0
Soluble to a clear glass, which, by a moderate addition of acid, is yellowish-green, and on cooling nearly colorless. Treated on charcoal it becomes opaque, but after cooling, of a fine green color.	The glass assumes a dark dirty green color, which on cooling changes to a fine clear green; this is analogous to the color presented by sesquioxide of chromium. Upon charcoal its behaviour is similar. An addition of tin has the effect of darkening this green tinge.	Fusible upon the platinum wire with effervescence, giving a clear glass, which on cooling becomes milky-white. When treated upon charcoal the mass is absorbed, and a large quantity of the molybdic acid is reduced. When levigated, the scoriae present the appearance of a steely-grey powder.	0
A large quantity gives a clear colorless glass.	First violet, then a blue glass.	Like tantalic acid.	A greyish glass while hot, dirty green when cold.

TABLE II.—COMPORTMENT

ACIDS.	On Charcoal, without Reagents.		With Borax on Platinum Wire.	
	In the Oxidating Flame.	In the Reducing Flame.	In the Oxidating Flame.	In the Reducing Flame.
28. Tungstic Acid. WO_3 .	Unchanged, if the flame is not a very strong one.	Blackens, but does not fuse.	Dissolves readily to a limpid colorless glass. A great proportion of the acid gives a yellow when hot; and a greater quantity imparts to the glass the property of appearing opaque in the flame. If an excess be present, the glass becomes spontaneously enamel-white on cooling.	A small quantity of the acid does not alter the color of the glass. A greater proportion renders it yellow. A still greater quantity produces a dark yellow when hot, which is yellowish-brown upon cooling. Tin darkens the colors, if the glass is not fully saturated.
29. Vanadic Acid. VO_3 .	Fusible. The portions found in contact with the charcoal are reduced and absorbed. The others assume the color and brilliancy of graphite. They are the protoxide of vanadium.		Soluble to a limpid glass, which by a small quantity of this acid is colorless; but by a greater addition becomes yellow.	The strongly yellow-colored glass changes, so that it appears brown when very hot, and on cooling of a beautiful chrome-green.
30. Tantallic Acid. TaO_3 .	Unchanged.		Soluble; forms a limpid colorless glass, which appears opaque in the flame. If more tantallic acid be added, it appears enamel-white on cooling.	As in the oxidating flame.
31. Titanic Acid. TiO_2 .	Unchanged.		Readily soluble to a limpid colorless glass, which, by a greater addition of the acid, becomes yellow, and is colorless after cooling. At a certain degree of saturation the glass appears streaked with enamel-white; if an excess is present, it becomes opaque on cooling.	A small proportion of the acid colors the glass yellow, while a larger quantity gives a dark yellow or brown shade. A glass when saturated appears enamel blue in the flame.

OF ACIDS.

With Microcosmic Salt on Platinum Wire.		With Carbonate of Soda.	With a Solution of Nitrate of Cobalt, in the Oxidating Flame.
In the Oxidating Flame.	In the Reducing Flame.		
Soluble, producing a clear glass; if more strongly saturated, the glass appears yellow while hot.	A beautiful clear blue glass is obtained. If the tungstic acid is combined with iron the color will be blood red. The glass containing the iron is colored blue when tin is added, and green if there is a considerable portion of iron.	Soluble upon the platinum wire, forming a dark yellow glass, which, when cooling, becomes crystalline and opaque with a tinge of white or yellow. Upon charcoal with a small quantity of soda a large quantity of the acid is reduced; by a greater addition of soda, the whole is absorbed by the charcoal. A conjunction of the shining metal and the yellow oxide of tungsten is often obtained with the soda.	0
As with borax.		It fuses with the soda, and is absorbed by the charcoal.	0
Dissolves readily and easily in large quantities, forming a colorless glass which cannot be rendered opaque in the flame, but which becomes spontaneously so upon cooling.	As in the oxidating flame.	It combines with the soda, effervescence taking place, but it is neither fused nor reduced.	0
Dissolves easily, forming a limpid glass, which, when containing a certain proportion of acid, is yellow when hot, and colorless upon cooling.	The glass, treated in the oxidating flame, presents the following appearances: when hot, the color is yellow, becoming, on cooling, red; and after assumes a beautiful violet tinge. When a greater quantity of the acid is added, the color produced is so intense that the glass appears opaque, but has not an enamel aspect. If the metal contains iron, the glass upon cooling will be brownish-yellow, yellow, or brownish-red. An addition of tin destroys this color produced by the iron, and the glass becomes violet.	Soluble, forming, after the effervescence and decrepitation has taken place, a dark yellow glass. The glass is not absorbed by the charcoal; after cooling, it appears greyish-white or white. If the glass is heated red hot, it crystallizes, and develops so much caloric that the bead spontaneously attains a white heat. The titanio acid is not reduced.	It is colored black, or greyish-black.

APPENDIX (C).

I FIND, at the last moment of going to press, that I have omitted all mention of the following apparently important facts: (1) If the nose be applied either just above, or at a considerable distance from the point of the artificial pyrocone, a strong *ozonous* smell is perceived, which is utterly absent from the side of the candle or gas "flame," and the smell of the gas pyrocone seems to differ slightly from that produced from a candle. (2) I find that *potassic carbonate* gives, with the minutest speck of pure rust, a pink-tinged bead on aluminum plate *after P.P.*, while sulphur gives a nearly similar tinge to a like bead *after H.P.*, so that herein is afforded an additional test for traces of iron, especially in sulphides, to that given at page 278. (3) Potash extracts a much larger quantity of carbon from an H.P. than soda on aluminum plate, while the *pyrochrome* in P.P. is *blue*, but violet in H.P.; a fact which seems an additional proof to that given at page 178 and elsewhere, that these red and violet tinges given to blue "pyrocones," are, at least in part, due to the burning of separated hydrogen. (4) The salmon-colored bead (see page 181, *d*) produced by the fusion of pure sulphur and soda on aluminum plate, turns purple ($2 \cdot 9$, Plate III.) after some hours; that formed by the treatment of soda with ordinary coal gas, turns grey (Plate IV.). (5) The *dispersive* power of a *didymic* glass, as shown by the different distances between the solar lines E and Eb in its spectrum, and in that given by yttria (Table VI.), which were taken with the same spectro-scope, should have been noted. (6) The metallic appearance given by a pure H.P. to the surface of beads of phosphoric, and boric acids, sulphur, and other "non-metals" (regarding the nature of which an opinion is reserved), can be produced so thickly as to be partly raised with the point of forceps, like thin tinfoil. It is necessary to mention here, that, by the courtesy and assistance of Messrs. William and Charles Griffin, of Garrick Street, I have, as I consider, improved part of the apparatus described, especially the stand for the table pyrocone (Fig. 11), which is now made like that of the lamp in the same figure, the heavy metallic block A being thus dispensed with. The arm C has also a place for a lens, which, with another one placed above on the same pillar, can be arranged so as to form a powerful microscope. The flat trumpet mouthpiece (Fig. 9) is now made of guttapercha, which I have tried, and find to answer admirably, while it packs well, but would it stand a hot climate? The whole apparatus is packed in a japanned case instead of in a portfolio (Fig. 56), but either can be used, as may be most convenient. Aluminum may be beautifully plated with silver, by simply boiling the strong nitrate solution of that, upon it, heating the residue strongly with the artificial pyrocone of a spirit lamp, and burnishing the plating with an ivory knife.

ADDENDUM.

THE GLASS STILL, for distilling small quantities of pure water at a time, briefly referred to at the end of the index, and contrived since this work has passed through the press, which will be found with the pyrological apparatus made for me by the Messrs. Griffin, and which is almost as simple as, though very much more efficient, than the rough mode of distilling water described at page 107, is thus made and used :

Two glass U tubes, with a bore of $\frac{3}{16}$ inch, 5.5 inches long, and having each the *left* side of the U bent over at top for about 2 inches, for connecting purposes, so that the entire breadth of the U at top is $3\frac{1}{2}$ inches, and at bottom only 2 inches, are fitted, one (*a*) into the washing-bottle, Fig. 23, two-thirds full of drinking water, so that the small end of the U passes right *into* the neck of the bottle, and is retained there by a *loosish* piece of vulcanized tubing; the other, (*b*) is fitted *upon* (*a*) with a *tight* piece of tubing. The apparatus is now placed with (*a*) dipping into a teacup, as it is next the spirit lamp, and a tumbler would there break; (*b*) dipping into a tumbler, so that the whole apparatus slants a little on one side as it rests on the inner edges of those. *No stand is required for the bottle*, under which a lighted spirit lamp is placed; and when sufficient water has been distilled, the bottle is gently (and easily) detached from (*a*) tube, *without putting out the spirit lamp*, by slipping the glass tube out of the vulcanized one, which remains firmly round the neck of the bottle. If the spirit lamp is blown out first, atmospheric pressure on (*b*) tube will of course force back part of the distilled water into the bottle. The condensing water in the cup is found to be moderately hot; that in the tumbler quite cold. About one-third of a shilling spirit lamp will, in this apparatus, distil sufficient pure water to fill the bottle, Fig. 24, in about quarter of an hour. Most waters boiled will leave a calcic alkaline coating inside the bottle, Fig. 23, which is easily removed by rinsing it well with water acidulated with phosphoric acid, but common vinegar will do.

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